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1939–1945

METEOROLOGY

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1939 - 1945
ROYAL AIR FORCE

METEOROLOGY

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Foreword

THE essential function of a meteorological service in war is to provide advice and information on the meteorological factors involved in strategic planning and tactical operations and, as a corollary, to develop and maintain an adequate technical service to meet those commitments. Although the strategic planning aspect is of the utmost importance, the necessary research and investigation can be performed by a comparatively small staff ; the provision of meteorological advice to meet the day-to-day tactical needs of Her Majesty's Services, on the other hand, requires a far reaching and flexible organisation.

During the war, the Meteorological Office provided the meteorological information and advice to the Armed Forces at home and abroad, to Government Departments and to essential services which were authorised to receive this secret information.

In the case of the Army and Air Force, the Meteorological Office had the sole responsibility. In the case of the Navy, the Meteorological Office's responsibility was limited to the supply of the basic reports and the technical deductions from them to the Naval Meteorological Service, which had the responsibility of advising the Admiralty and supplying forecasts to H.M. ships and naval shore establishments, other than Combined Headquarters, where the Meteorological Office was responsible for providing the technical staff and the technical advice.

To meet the needs of the Air Force and Army, meteorological offices had been, or were subsequently, established at the Headquarters of the Commands, Groups and Corps, and at most operational airfields, and at a number of specialised Army Units.

In Overseas Commands, the Chief Meteorological Officer was effectively the meteorological Theatre Commander, dependent for general guidance and supplies on his Headquarters in London, but with full technical responsibility for the meteorological advice to the Armed Forces in his Theatre.

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METEOROLOGY

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Part I

THE METEOROLOGICAL SERVICE UP TO THE OUTBREAK OF WAR IN 1939

CHAPTER 1

THE PROVISION OF METEOROLOGICAL FACILITIES PRIOR TO SEPTEMBER 1939

The Royal Air Force

When the Meteorological Office was incorporated in the Air Ministry in 1919, the Royal Air Force was being rapidly reduced in strength, and, for a number of years, liaison with the Air Staff and the Royal Air Force was effected normally through the Director of Training. By 1929, however, closer liaison was clearly needed and a conference on the supply of meteorological information to the R.A.F., held in August of that year, recommended that a permament Royal Air Force Meteorological Committee should be formed with representatives of the Air Ministry branches and Commands concerned. Such a committee was accordingly set up under the chairmanship of the Director of the Meteorological Office as an advisory committee on technical matters.

The rapid expansion of the Royal Air Force from 1935 emphasised the need for something more than a purely technical committee and, in January 1937, the Chief of the Air Staff suggested the formation of a committee to consider the policy problems involved. The Royal Air Force Meteorological Committee then recommended that a Royal Air Force Meteorological Policy Committee and a Royal Air Force Meteorological Technical Committee should be formed. The terms of reference of the Policy Committee, which was under the chairmanship of the Assistant Chief of the Air Staff, were ' to ensure that the meteorological services are adequate to meet the needs of the Royal Air Force.[1] The Technical Committee was intended to supersede the Royal Air Force Meteorological Committee, and its duties were to advise the D.M.O. on any technical questions which he might put to it. In practice, however, the Technical Committee as such never functioned, its duties being performed by *ad hoc* sub-committees of the Policy Committee. The Policy Committee held its first meeting in March 1937 and continued to meet until December 1941 after which it was allowed to lapse. It was resuscitated in June 1944 with extended terms of reference.

Reorganisation to meet the Needs of the Royal Air Force at Home

Prior to 1934, the policy had been to provide meteorological ' distributive ' (*i.e.*, forecasting) stations at night bombing and flying boat stations and at flying training schools. No night duty was performed at these stations which were open from 0600 G.M.T. (0400 G.M.T. in summer) until 1800 G.M.T. for observational purposes, and from 0900 until 1700 clock time (1300 on Saturdays) for forecasting purposes.[1] In October 1934, the A.O.C.-in-C., Air Defence of Great Britain, suggested a reorganisation of the meteorological service in which a group of airfields would be served by one meteorological centre operating throughout the twenty-four hours.[2] This suggestion for a group system for

[1] A.M. File 493840/24. [2] A.M. File S.35480.

meteorological offices was opportune as the Air Ministry were planning to replace the existing R.A.F. point to point W/T system by a teleprinter network, and it was considered that a meteorological teleprinter system on the proposed group basis could readily be superimposed on the R.A.F. network.

A first draft reorganisation, based on the group system and designed to meet the needs of both the Royal Air Force and Civil Aviation, was produced in March 1935. It visualised a number of main meteorological centres distributed over the country each in close contact with the Meteorological Office, Air Ministry, and each acting as a distributor of data and forecasts to a group of subsidiary offices. These latter were to be manned differently according to their functions. In all, four different types of meteorological office were proposed :—

Type A. The main centre of each group at which synoptic charts would be prepared and forecasts made. The Type A Office would also be responsible for making the normal synoptic observations.

Type B. A Type B office would meet the need where two or more stations in the same vicinity each required forecasters. Only one of these would have a Type A office, the others having Type B. The Type B office would receive from the Type A office sufficient data to plot synoptic charts and copies of the forecasts prepared at the Type A office. Observations for local use would be made and information supplied on demand.

Type C. Type C was intended for airfields at which synoptic charts, and staff to explain them intelligently, were required although the actual forecasts would be obtained from the appropriate Type A office.

Type D. A Type D office was to be provided at stations where no synoptic charts were required. An assistant or observer would receive current observations and forecasts from the appropriate Type A office would be available to obtain special meteorological information required at the airfield and would also make observations as required.

These four types of meteorological office formed the basis of all later schemes. In the draft reorganisation, it was proposed to allot Type A or B offices to all Area Headquarters, Flying Boat Stations and Flying Training Schools as hitherto, Type C offices to night bomber stations which were near to a Type A office, and Type D offices to each light bomber station to provide information for cloud flying. No provision was made for meteorological offices on fighter airfields. Fourteen main group centres were proposed, at eleven of which there was already a distributive unit which could act as a Type A office. In addition, six independent Type A offices were suggested as possible centres for future groups if required. The communications visualised for the scheme involved the use of wireless from Air Ministry to the group centres, with teleprinters as a desirable ultimate arrangement, and direct communication between the Type A offices and their subsidiary offices, preferably by teleprinter.

This draft organisation was circulated for comment in Air Ministry and to the Headquarters of the Air Defence of Great Britain, Inland Area and Coastal Area. As a result, a revised proposal was produced in December 1935, based on Expansion Scheme C and on the proposed distribution of squadrons at the end of the financial year 1938–39. The fundamentals of the scheme were as

before, but the changed organisation of the R.A.F. required a reconsideration of a number of problems. The revised proposals, which it was intended to put into effect in step with the stages of the R.A.F. programme, were as follows :—

Bomber Command. 24-hour forecasting centres with a senior technical officer in charge of five forecasters at each heavy and medium group headquarters.

Forecasting centres primarily for daylight hours with two forecasters at each light bomber group headquarters. Type C offices at heavy and medium bomber airfields.

Fighter Command. No decision was made as to the need for Type A offices at fighter group headquarters and/or Fighter Command Headquarters.

No provision was made for meteorological offices on fighter airfields.

Coastal Command. Only existing Coastal Area Stations were shown in the memorandum.

Training Command. No provision was made in the memorandum for the flying training schools.

The proposal was approved provisionally by the Air Ministry in February 1936, on the assumption that it would be adapted to fit Expansion Scheme F, and was considered in detail at a conference in June 1936. The reorganisation approved by the Treasury in April 1937, was designed to meet peace-time meteorological requirements.[1]

The war-time requirements of the Royal Air Force at home had been considered at a conference in May 1936, at which the revised proposals of December 1935 were available. It was agreed that the new peace-time proposals would meet war-time requirements except that :—

(*a*) The Type 2 offices at fighter group headquarters would need to be upgraded to Type 1.

(*b*) Each Coastal Command war station would require a meteorological office, all Type 2 except for one Type 1.

This would probably involve nine additional Type 2 offices and one Type 3 office.

Although the peace-time scheme had been approved, it could not be put into effect until the necessary staff had been recruited and trained. In January 1937, the D.M.O. suggested two possible interim arrangements :—

(*a*) The establishment of self-contained forecasting units (Type 3) on selected aerodrome with W/T receivers and W/T personnel for the reception of meteorological information broadcast from Air Ministry. This would give a 44 hours service a week, divided between day and night service at the discretion of the Station Commander.

(*b*) The provision of 24-hour meteorological offices (Type 1) at three of the following stations—Abingdon, Andover, Mildenhall, Cranwell and Catterick—and instruct units to obtain information from the nearest by telephone.

[1] A.M. File S.37271. From that time onwards, the main types of meteorological office were denoted by figures instead of letters.

The C.A.S. ruled that the first alternative should be adopted, and asked for an estimate of the time required to complete the full Scheme. The D.M.O. replied that the rate of expansion of the meteorological service had been slowed down by the difficulty of obtaining the necessary scientific staff, by the loss of trained professional staff to meet meteorological needs elsewhere and to train recruits and by the need to give training in forecasting to a large number of the existing assistants. As it took at least eighteen months to train a man to issue independent forecasts, the expansion of the meteorological service was bound to be slow. In March 1937, the D.M.O. estimated that by 1 May 1937 all but two of the main forecasting stations and eight of the subsidiary stations then required by the R.A.F. and civil aviation would have been provided. By the first quarter of 1938, all the meteorological stations required by the R.A.F. and civil aviation would have been provided.

The general policy having been determined, the problem was largely one of deciding the order in which meteorological offices should be established as the R.A.F. stations were opened and meteorological staff became available, and a sub-committee of the R.A.F. Meteorological Policy Committee was set up to deal with the question. This Priority sub-committee decided in August 1937 on a priority based on the following categories :—

Class A : those which it was desirable to provide during the financial year ending 31 March 1938.

Class B : those which it was desirable to provide during the first six months of the financial year 1938–39.

Class C : those which should be provided during the second six months of the financial year 1938–39.[1]

Within each category, the order of priority was as follows :—

(*a*) Command and Group H.Q. meteorological offices, especially those of Bomber Command.

(*b*) Bomber Command station requirements, the priority to be allotted so that the staff available should be distributed over as wide a geographical area as possible rather than meet the needs of each Bomber Group in turn.

(*c*) Subsequently, as staff became available in larger numbers, individual Bomber Group requirements were to be met, but, as in (*b*) above, on a geographical basis.

A detailed priority list, based on the above principles, was drawn up and was approved in September 1937.

Up to then, the decision that the peace-time complements of the meteorological offices at home would be adequate to meet war-time requirements had been accepted as the basis on which staff requirements were computed, but a decision by the R.A.F. Meteorological Policy Committee that in war a 24-hour for seven days a week should be provided by the meteorological offices at all operational R.A.F. war stations altered the whole scale of the staff problem.[2] It was estimated, on the basis that all staff would work eight hours a day for seven days a week, that a minimum of 64 additional professional officers and 238 assistants would be required on the outbreak of war. This problem led ultimately to the formation of the Meteorological Section of the R.A.F.V.R.

[1] A.M. File S.42164. [2] A.M. File S.32863.

The international crisis of September 1938 necessitated a further review of priorities as there was still an acute shortage of meteorological staff. It was agreed on 12 September 1938 to allocate the staff available for home stations to provide 24-hour meteorological offices in the following order of priority :—[1]

Priority 1 : Bomber, Coastal, Fighter Command Headquarters, Bomber and Reconnaissance Group Headquarters.

Priority 2 : Fighter Group Headquarters.

Priority 3 : Bomber and G.R. war stations.

Special consideration was to be given within priority 3 to outlying stations which were not in good communication with their Group Headquarters. A statement[2] of the units which it was possible to provide was agreed, with a few minor amendments, by the Commands.[3] The staff moves needed to effect the proposals were made on 28 and 29 September 1938, but on 8 October 1938, the staff were ordered to revert to their home stations.

A sub-committee of the R.A.F. Meteorological Policy Committee prepared, in November 1938, a revised peacetime priority list based on Expansion Schemes F. and L. Shortage of staff was still the major difficulty and although the formation of a meteorological section of the R.A.F.V.R. was sanctioned in April 1939, its effect could not be felt for some time. Statements were prepared in May 1939 of the immediate and ultimate R.A.F. war-time requirements for meteorological offices[4] and the Air Staff ruled that the order of priority in allocating staff in an emergency should be as follows :—[5]

Priority 1 : All Operational Command and Group Headquarters except that Fighter Command could have reduced staff in the initial stages.

Priority 2 : Bomber and General Reconnaissance war stations.

Priority 3 : Fighter Command war stations.

Priority 4 : Training Command, except that Schools of Air Navigation and Air Observer Schools should be left fully staffed. Personnel from other stations in the Command could be used to make up the establishments of the Operational Commands if required.

This order of priority remained in force until September 1939, and the final moves of the staff to war stations were made on that basis.

Meteorological Facilities for the Royal Air Force Overseas

The meteorological needs of the R.A.F. overseas were met, in the main, by the local governments and were outside the control of the Meteorological Office. The Meteorological Office maintained establishments in Gibraltar, Malta, Egypt, Palestine, Transjordan and Iraq only,[6] while the meteorological services for the R.A.F. in East Africa, Sudan, India, West Africa, Malaya and Hong Kong were provided by the local governments. Liaison on matters of policy was effected through the Dominions, India and Colonial Offices. The

[1] A.M. File S.46303. [2] *See* Appendix 1. [3] A.M. File S.48136.
[4] *See* Appendix 4. [5] A.M. File S.46303. [6] A.M. File S.45260.

following meteorological facilities were being provided for the R.A.F. overseas in October 1938:—

Gibraltar: A forecasting unit was established as Windmill Hill Flats in October 1935 during the international crisis, and had been retained primarily to meet the needs of the Navy and Army at Gibraltar.

Malta: A forecasting unit has been established at Guardamangia in 1922 to provide meterological advice for the Services on the island. In 1927, the meteorological station was moved to St. John's Cavalier.

Egypt: During the previous ten years, civilian Meteorological Office staff had been maintained in Egypt to meet the requirements of the R.A.F. They were located at R.A.F. stations, the main centre being at Heliopolis, with two sub-stations at Aboukir and Ismailia. It had been recommended in 1935 that the Egyptian Government should eventually assume responsibility for the supply of all meteorological information for aviation in Egypt, including that for the R.A.F. It was visualised, however, that the aviation meteorological service would continue to be controlled by the Air Ministry for the next eight years and that, when control passed to the Egyptian Government, a technical officer of the Meteorological Office should be attached to Headquarters, Middle East, to act as liaison officer with the Egyptian Meteorological Service.

Palestine and Transjordan: The Palestine Meteorological Service which was being formed by the Palestine Government with its main forecasting centre at Lydda airport, was due to take over from Heliopolis, on 1 October 1938, the responsibility for aviation forecasts in Palestine and the area extending to Egypt, Cyprus and the Iraq border. The Director of Civil Aviation, Palestine, had also offered to supply by teleprinter all the meteorological information required by the R.A.F. at Ramleh, and to staff the meteorological sub-office at Ramleh.

Iraq: The Meteorological Office maintained a forecasting centre at Habbaniya and a sub-office, which did not issue independent forecasts, at Shaibah. The Iraqi meteorological service for civil aviation, which was established in 1932, had its main forecasting centre at Baghdad and a sub-office at Basra. Both the Director of the Iraqi Meteorological Service and the officer-in-charge at Basra were seconded from the Meteorological Office for duty with the Iraqi Government, but an Iraqi was expected to replace the British Director within a few years.

Aden: The only meteorological service provided at Aden was an observing unit maintained by the India Meteorological Department. Meteorological staff had been posted to Aden during the crisis of October 1935 to open a forecasting unit but, despite the Admiralty and Air Council view that a meteorological office at Aden was necessary in peace-time, the meteorological staff were withdrawn in November 1936 because of the acute shortage of meteorological staff elsewhere.[1]

East Africa: The East African Meteorological Service was established in 1929, under the Conference of East African Governors, and met meteorological requirements in Kenya, Uganda, Tanganyika and Zanzibar.

[1] A.M. Files S.28466 and S.36727.

It was handicapped at first by the lack of international co-operation in Africa, but rapid progress in building up an aviation forecasting service followed the decision of the Meteorological Organisation in 1935 to set up a regional commission for Africa.

Sudan: Towards the end of 1935, the Sudan Government had established its own meteorological service, which was reinforced temporarily by Meteorological Office staff during the Abyssinian crisis. A contribution towards the cost of the service was made from Air Votes in respect of meteorological facilities for the R.A.F. squadron stationed in the Sudan.

India: The meteorological requirements of the R.A.F. in India were met by the India Meteorological Department, under the Director-General of Observatories. A number of the Meteorological staff, seconded for duty with the R.A.F. at Peshawar, worked in collaboration with the India Meteorological Department.

West Africa: The Conference of Empire Meteorologists in 1935 discussed the meteorological facilities for the proposed air mail route from Khartoum through Kano to Lagos. As a result, the Governor of Nigeria was asked to provide an aviation forecasting service with full-time meteorologists. A service was organised under the Commission of Lands and Surveyor General, and by October 1936 forecasting sections were functioning at Kano and Lagos.

Malaya: The Malayan Meteorological Service, established in 1929 under the Department of the Surveyor-General, was responsible for the supply of meteorological information to the Officer Commanding, R.A.F., Far East. At first, financial stringency and the lack of international meteorological organisation in the Far East made it difficult for the Malayan meteorological service to meet its commitments. In March 1935 the attention of the Colonial Office was drawn to its shortcomings and to the fact that the service, already inadequate, would have to meet the still greater demands of the aviation developments which were then taking place. The position improved considerably in the following years, conferences with representatives of the Australian, Indian, Dutch and Siamese meteorological and communication services leading to more regular and more comprehensive broadcasts of data from neighbouring territories and action being taken to arrange for reports from North Borneo and Sarawak. Additional forecasting and observing staff were also obtained.[1]

Hong Kong: The meteorological service at Hong Kong, provided by the Royal Observatory, was intended primarily for issuing typhoon warnings for the colony and for local shipping interests, and not for aviation forecasting. The staff had little knowledge of aviation requirements and insufficient data were available from neighbouring territories. The visit of No. 205 (F.B.) Squadron to the South China Sea in 1934 had emphasised the weakness of the service and, in December 1934, the Air Ministry asked for action to be taken to improve matters. The question was taken up with the Colonial Office in March 1935 at the same time as the Malayan

[1] A.M. File S.35432.

question. The Conference of Empire Meteorologists in London in 1935 provided an opportunity for explaining requirements to the Director of the Royal Observatory, and in August of that year the Governor of Hong Kong reported that steps were being taken to obtain the necessary staff and equipment to form the nucleus of an aviation forecasting service.

A sub-committee of the R.A.F. Meteorological Policy Committee, which had been set up in the spring of 1938 to examine the overseas meteorological requirements of the R.A.F., reviewed in October 1938 the overseas meteorological facilities. It agreed that in general the existing facilities, including those provided for civil aviation, were adequate for R.A.F. requirements but recommended certain modifications. It also agreed that Headquarters, R.A.F. India, and Headquarters, R.A.F. Far East, should be asked for their view on the meteorological services for their areas. The suggested modifications were :—

Gibraltar : The meteorological office, which had to be moved from Windmill Hill Flats, should be re-sited at Europa Point.[1]

Egypt : The main forecasting centre should be moved to Alexandria a Type 2 office established at Heliopolis, and Type 3 offices provided as necessary during the moves of the units to the Canal Zone.

Malta : The existing 16-hour service should be extended to a 24-hour service.

Cyprus : A network of observing and pilot balloon stations should be developed to meet the needs of civil aviation.

Palestine and Transjordan : The proposal of the Palestine Director of Civil Aviation that the Palestine Government should provide the meteorological service for Ramleh and Amman should be accepted.

Persian Gulf : A full forecasting centre should be established at Bahrein when the proposed move of a flight of No. 203 squadron to that place occurred. Until then, the forecasting centre should be opened at Shaibah, ready for transference, and the existing reporting station at Shaibah should be taken over from the Indian Government.

Aden : A full forecasting centre should be established at Aden, with reporting stations in the Red Sea, South Arabian Coast and Socotra. The service should be established at once not so much to deal with the local requirements of the Aden forces as to study the meteorological conditions of the whole neighbourhood.

Saudi Arabia : Efforts should be made to obtain meteorological reports from the W/T station in the interior of Arabia. Negotiations to this end had been opened through the Foreign Office in 1935 but had not been pursued.

These recommendations of the sub-committee were approved in January 1939. The Air Officers Commanding India and Far East were asked to give their views on the meteorological services in their areas and Treasury approval for the establishment of an office at Aden was sought.[2]

[1] A.M. File S.45260.

[2] A.M. File 872802/39 Encl. 5.

The Air Officer Commanding, Far East, replied that the meteorological services of Malaya and Burma were well organised and efficient and that the staff appeared to be adequate to meet requirements during operations. The Hong Kong meteorological service appeared to be reliable although little information was available about it. The meteorological service of Ceylon was at that time, however, unable to supply route forecasts for the Ceylon-Singapore route. A number of handicaps were also mentioned, notably the lack of ships' reports, and upper data from Burma and Ceylon. Also, the Malayan Meteorological Service depended to a considerable extent on reports from foreign countries.[1]

The reply from the Air Officer Commanding, India, suggested that the existing service in India could be improved by a general speed up of communications, an increase in the number of observations per day from existing stations, the opening of new observing stations, the training of the part-time observers who were mainly clerks in Government offices, and liaison with the Government Departments concerned to ensure that the trained observers were not posted too frequently and replaced by untrained men. The possibility of initiating a meteorological reporting organisation in Persia and accelerating the provision of one in Afghanistan was advocated, as was the inception of a separate broadcast of reports from Russian Turkestan.

By the time the replies were received from the Air Officers Commanding, attention was concentrated on the requirements for a European war and no further action was taken for some time. The Treasury approved the establishment of the office in Aden in July 1939, and the staff needed to open the station left the United Kingdom on 23 September 1939.[2]

The Royal Navy

When it was agreed in 1919 that the Meteorological Office should become a part of the Air Ministry, a Naval Services division of the Meteorological Office was formed to maintain liaison with the Admiralty and to deal with the meteorological requirements of the Fleet. Liaison was usually effected by the Naval Services Division through the Hydrographic Department of the Admiralty. During the next ten years, a steadily increasing interest in meteorology was shown by the Admiralty. This was due largely to the development of aircraft carriers, but the fundamental importance of meteorology in many other aspects of fleet operations and naval warfare was also realised, and in 1928 a Fleet Meteorological Committee, on which the Meteorological Office was represented, was appointed by the Admiralty to advise their Lordships on all meteorological questions affecting the Navy.

The problem of providing meteorological information for the Navy was radically different from that of providing similar facilities for the Army and R.A.F. The training of naval officers in meteorology and the development of a naval meteorological service continued steadily until a stage was reached where the administration of the service could not be carried out efficiently if it remained centred in the Air Ministry, as many questions of detailed administration could not conveniently be separated from other naval questions. The Air Ministry, the Admiralty and the Treasury agreed, therefore, that the

[1] A.M. File S.45260.

[2] A.M. File 872802/39.

Naval Services Division should be transferred to the Admiralty on 1 August 1937 on the understanding that only administrative functions should be transferred to the Hydrographic Department and that the transfer would not result in the setting up of a second organisation in parallel with the Meteorological Office.[1]

The services rendered by the Meteorological Office to the Royal Navy during the years 1919–1939 were as follows :—

(*a*) The organisation of meteorological work on H.M. ships.

(*b*) The organisation of the supply of information from shore meteorological services to meet the needs of the Fleet in all parts of the world.

(*c*) The training of Royal Navy personnel in meteorological work.

(*d*) The revision and preparation of meteorological publications for naval use, including the meteorological section of Admiralty 'Pilots' (handbooks issued by the Admiralty for the use of Navigators) and of Weather Handbooks dealing with the various naval stations at home and overseas.

(*e*) Preparations to ensure the continued efficiency of the naval meteorological service in the event of war.

Organisation of Meteorological Work on H.M. Ships

During the first few years after the First World War, the Fleet relied for its meteorological information on Fleet Weather Forecasts compiled in the Meteorological Office and broadcast by Admiralty wireless stations. General Weather Shipping Bulletins were introduced in 1924, and the Fleet Weather Forecasts were then discontinued and arrangements made for the Weather Shipping Bulletins to be intercepted by the Admiralty wireless stations and passed on to the respective Senior Naval Officer. During the next few years a number of naval observers were trained in forecasting and posted to aircraft carriers for forecasting duties. These officers were responsible not only for issuing forecasts to the aircraft carried on the ships, but for providing general forecasts to the Fleet twice daily. The organisation of the meteorological service afloat was further stimulated by the formation of the Fleet Meteorological Committee, and by 1930 a complete and, as far as possible, uniform organisation for aircraft carriers was being developed. This involved many problems of detail peculiar to the organisation of a meteorological service afloat.

The naval meteorological organisation had expanded still further by 1936, and Instructor Officers, qualified in Meteorology, were being appointed to Flagships and certain other ships other than aircraft carriers. The meteorological staff on aircraft carriers consisted of an Inspector Officer, a Naval Observer qualified in meteorology and a trained rating to assist in the more routine duties. The daily routine consisted of plotting synoptic charts and charts of upper air conditions according to the data available, making surface observations at the standard hours, and observations of upper winds and upper air temperatures. Forecasts were prepared for operations of the Fleet and the Fleet Air Arm. Meteorological duties on ships which did not carry qualified Instructor Officers or Observers were performed by the Navigating Officer. Within a Fleet, the Fleet Navigating Officer was responsible to the Commander-in-Chief for the meteorological organisation of the Fleet on the station, and

[1] A.M. File 388181/35

Squadron Navigating Officers were responsible for the organisation in squadrons other than aircraft-carrier squadrons, the senior meteorological officer being responsible in the latter. No change in policy regarding the meteorological service afloat resulted from the transfer to the Admiralty in 1937 of the administration of meteorological work in the Navy, and development continued on the lines already laid down until the outbreak of war.

Supply of Information from Shore Meteorological Services

One of the difficulties involved in developing a forecasting service on board ship was the reception of the large amount of data required before synoptic charts could be plotted. This normally involved intercepting broadcasts made by a number of countries. Wireless reception facilities on board ship were limited, however, and one of the first tasks involved in the decision to appoint forecasting officers to H.M. ships was the organisation of special collective messages containing only the data needed for the work of the naval forecasting officers. These special messages were known as Fleet Synoptic Messages or Fleet Synoptics.

The first Fleet Synoptic was the Malta Fleet Synoptic, which was started in May 1925 and designed to meet the needs of the Mediterranean Fleet. The Hong Kong and Malaya Fleet Synoptics began in 1932. Financial stringency prevented the Indian Government from transmitting a Fleet Synoptic from India until 1936, but an abbreviated Fleet Synoptic was issued from Ceylon. The South African and Canadian Fleet synoptics were started in 1933 and 1934 respectively, but the commencement of an East African Fleet Synoptic was delayed, again on financial grounds. However, with the issue of messages of the Fleet Synoptic type from Australia, Suva and Apia in 1934 and from New Zealand and the United Kingdom in 1935, a world wide network of synoptic messages and forecasts, issued specifically to meet naval requirements, began to take shape.

Training of Personnel

The first course in meteorology for naval observers was organised at Calshot in 1925. During the following years a number of *ad hoc* courses were organised at the Meteorological Office in London. In 1928 it was decided to hold all the meteorological courses in London and the following three types of course were arranged :—

(*a*) Three months' course for selected naval observers.

(*b*) One month's refresher course for naval observers who had undertaken meteorological duties on carriers for about two years.

(*c*) One week's meteorological course for surveying officers and officers on the staff of the Navigation School.

In 1931, the courses were elaborated and subdivided as follows :—

(*a*) Three months' course for naval observers.

(*b*) Three months' course for surveying officers.

(*c*) One month's advanced course for naval observers.

(*d*) One month's course for surveying officers.

(*e*) One week's course for navigating officers.

(*f*) One week's course for surveying officers.

Officers of the Royal Australian Navy, Royal Canadian Navy and Royal Indian Marine attended a number of these courses, and it was agreed in 1936 that selected R.N.V.R. officers should attend the three months' course. By the end of 1937, in which year the administration of the training courses was transferred to the Admiralty a total of 73 officers had qualified in meteorology.

Preparations for War

The first comprehensive statement of the Fleet's war time meteorological requirements was prepared as Naval Division Memorandum 55–34, produced for the information of a sub-committee of the Fleet Meteorological Committee which had been set up to consider the war-time organisation of Fleet-meteorology.[1] The sub-committee's report, which was, in effect, Naval Division Memorandum 55–34 with minor alterations, was approved by the Board of Admiralty in October 1935,[2] and arrangements were made to give effect to those recommendations which concerned the internal organisation of meteorology in the Fleet. A number of other recommendations, including those affecting the general war organisation of meteorology, were referred to the Air Ministry in October 1935.

The Air Ministry, replying in March 1936, agreed generally with the Admiralty proposals and stated that action had already been taken to produce a meteorological cypher, that the preparation of a special series of monthly charts of visibility, cloud types and amounts would be undertaken, and that the reports on the vulnerability of naval bases to chemical attack would be prepared at Porton. They agreed that a meteorological office at Aden with a network of observing stations was necessary in peace-time and that the retention of the temporary forecasting centre at Gibraltar would be considered. They suggested that the general subjects of obtaining meteorological reports from allied and neutral countries in war should be discussed at a conference and that, when the general lines of the war organisation had been agreed, the Meteorological Office would approach the Dominions and Colonial meteorological services in order to obtain their co-operation. This proposed inter-service and inter-departmental conference was, for a number of reasons, never held, and the various aspects of the war organisation were tackled separately.

The temporary forecasting centre at Gibraltar, which had been opened in 1935, was retained, primarily to meet the needs of the Army and Navy, but that at Aden was closed. The War Office stated in 1938 that a meteorological office could be required at Aden in war-time and a sub-committee of the R.A.F. Meteorological Policy Committee decided in October 1938 that a forecasting office was required there in peace-time, but the office was not eventually opened until September 1939.

The international crisis of September 1938 necessitated a more specific examination of naval requirements, particularly as regards the supply of the necessary meteorological information to home bases. Such information was required by Admiralty Headquarters, Mount Batten, Invergordon, Portsmouth, Portland, Chatham or Sheerness, Rosyth and the Main Base of the Home Fleet. Meteorological offices already existed to serve Mount Batten and Invergordon, Portsmouth was served by the meteorological office at Coastal

[1] *See* Appendix 3. A.M. File S.36435.

[2] The delay in obtaining approval was due to an interim Mediterranean War Organisation being approved in view of the International situation in 1935.

Command Headquarters and the needs of Rosyth could be met by the meteorological office at Donibristle. It was agreed that the proposed Type 3 office at Warmwell should be upgraded to a Type 2 to meet naval needs at Portland, and arrangements were made to post meteorological staff to Chatham, and to open a forecasting office in the Admiralty manned by two technical officers of the Meteorological Office and two Naval meteorological officers. The question of the Home Fleet was left open as communications difficulties were likely if it were situated in the north of Scotland.

The main new points of the consolidated statement of naval requirements at home, issued in March 1939, were the addition of Pembroke to the list of naval bases, a statement that the Naval Meteorological Service would take over the responsibility for Rosyth and Portsmouth from January 1939, and certain modifications in the form of the Home Fleet Synoptic.[1] The only other major modification before the outbreak of war was a decision in July 1939 that the Naval Meteorological Service would man the forecasting office at the main base of the Home Fleet and that the technical officers of the Meteorological Office would not be required for the forecasting section in Admiralty Headquarters. A Naval Meteorological Liaison Officer was posted on 26 August 1939 for duty at the Central Forecasting Office of the Meteorological Office. On the same day, the Home Fleet Synoptic was issued in cypher, the first of a series which was to continue until the end of the war in Europe.

The provision of forecast services at naval bases overseas was raised again by the Admiralty in June 1939. The requirements were then stated to be as follows :— [2]

(*a*) *Places where new forecast centres, with a 24-hour service would be required in war, and where limited forecast services were desirable in peace.*—Alexandria, Kingston (Jamaica), Simonstown, Aden, Barbados, Halifax (Nova Scotia), Freetown (Sierra Leone).

(*b*) *Places where dormant forecast centres would meet requirements in peace, but where a 24-hour service would be required in war.*—Haifa, Trincomalee, Labuan.

(*c*) *Places where forecast centres were already in existence, but where a 24-hour service would be required in war.*—Gibraltar, Darwin, Apia, Malta, Brisbane, Esquimalt, Colombo, Melbourne, Bermuda, Mauritius, Sydney, Lagos, Dar-es-Salaam, Freemantle, Durban, Singapore, Wellington, Hong Kong, Suva.

The Admiralty requested that these requirements should be brought to the attention of the Dominions and Colonial Meteorological Services concerned, who should be informed that, subject to their concurrence, it was proposed to post naval meteorological liaison officers to the headquarters of each service in the event of war.

As they considered that some of the Colonial Meteorological Services would not be able to meet these commitments, the Air Ministry made the following proposals to the Colonial Office in July 1939 when informing them of the Admiralty requirements :—

(*a*) *Colombo, Singapore, Hong Kong, Dar-es-Salaam, Lagos.*—The necessary provision should be made by the Colonial authorities.

[1] A.M. File S.46303.

[2] A.M. File S.45299.

(*b*) *Suva.*—The Government of New Zealand should be asked to supply the meteorological staff.

(*c*) *Barbados and Freetown.*—Meteorological Office forecasting centres should be established, similar to those provided at Gibraltar and Malta.

(*d*) *Kingston, Mauritius, Bermuda, Haifa, Trincomalee.*—Where necessary, the existing service should be strengthened by the attachment of forecasting officers of the Meteorological Office.

(*e*) *Labuan.*—Provisional arrangements should be made to open an office with forecasting officers of the Meteorological Office.

Parallel letters were sent to the Dominions and India Offices on 5 August 1939, but in these cases it was assumed that the Dominions and Indian Meteorological Services would be in a position to meet the specified requirements without external assistance.[1] War had been declared, however, before the replies, all of which were favourable, could be received.

Another aspect of the preparations for war was the trial encyphering of Fleet Synoptics. In accordance with Admiralty Fleet Order S.113/1937, the naval authorities and shore meteorological services arranged for trial Fleet Synoptics to be broadcast in cypher in order to reveal any unforeseen difficulties and to give the staff concerned experience in encyphering and decyphering the messages. Such exercises were held on a number of naval stations as the opportunity occurred when H.M. ships were in the vicinity on cruise or in passage, and a regular series of trials was begun for the Home Fleet Synoptic on 17 May 1938, one Synoptic Message being encyphered each month.[2]

The Army

Apart from the arrangements for the Expeditionary Force, the following meteorological facilities were provided for the Army before the war, or contemplated in the event of war :—

(*a*) Permanent forecasting and observing units at War Office training and experimental establishments.

(*b*) Seasonal observing units at artillery practice camps during the summer months.

(*c*) Artillery Meteor reports provided to artillery units at defended ports at home and abroad.

(*d*) Anti-aircraft Meteor reports supplied to the Inner and Outer Artillery Zones of the Air Defence of Great Britain and to local air defences.

Permanent Offices at War Office Establishments

During the period 1918 to 1939, three permanent meteorological offices were maintained at War Office training and experimental establishments. Two of these, Shoeburyness and Larkhill, had been established during the first World War and continued to function after the war as civilian establishments, and the third, Porton, was opened in January 1921 when three of the professional staff of the Meteorological Office were seconded for duty with the War Office authorities.

[1] A.M. File S.45299.

[2] A.M. File S.24337.

Shoeburyness : The task of the meteorological section attached to the War Office Experimental Establishment at Shoeburyness was to provide the Superintendent of Experiments with the meteorological advice and data needed for the work of the establishment. This consisted mainly of calculating the corrections required to allow for air density and wind speed and direction during experimental shoots with shells of various calibres and trajectories. 'Weighting factors' were computed for the conditions in the various layers of the atmosphere through which the shell passed, and the actual conditions prevailing in the various layers were measured while the shoot was in progress. The results were then applied as corrections in determining the range and accuracy of the shell. The meteorological factors involved in rocket firing were also investigated during the development of these projectiles at Shoeburyness.

The upper winds were measured by pilot balloons (small hydrogen-filled balloons whose course and altitude could be determined by means of special theodolites). From data obtained in this way, the wind speed and direction at any level could be determined. The temperature of the air at various levels, required to calculate the density of the air, was at first measured by thermometers attached to a kite balloon but this method was abandoned in 1924 when the meteorological flight was established at Duxford, as it was found that the values determined during the aircraft ascents could be applied to Shoeburyness with sufficient accuracy.

Work was also done at Shoeburyness on the acoustical conditions in the atmosphere. A technique was developed for sound ranging on shell bursts in the air when cloud conditions precluded direct observation.

Larkhill : The meteorological data required by the School of Artillery at Larkhill were originally provided by the meteorological office at West Lavington, but in 1920 the section responsible for the supply of meteorological data to the School of Artillery moved to Larkhill. The work of the meteorological office at Larkhill was similar to that at Shoeburyness, general forecasts being provided for the School of Artillery and meteorological corrections computed for calibration trial and practice shoots.

The Sound Ranging Section of the 1st Survey Company of the Royal Artillery was engaged at Larkhill on developing methods of sound ranging on enemy batteries, and in August 1936 the War Office asked for additional Meteorological Office staff to be posted to Larkhill to specialise in sound ranging work. The Treasury agreed in July 1937 and the additional staff were attached to the existing meteorological office. The staff was further strengthened by the temporary attachment of assistants from other meteorological offices when intensive continuous pilot balloon work was required for sound ranging purposes, or when the Sound Ranging Section was operating away from Larkhill.[1]

Porton : The task of the Meteorological Department of the Chemical Defence Experimental Station at Porton was to serve the Station in all matters relating to meteorology and, in particular, to conduct research into the meteorological problems arising in chemical warfare. This

[1] A.M. File S.37349/I.

involved intensive investigation of the complex mathematical-physical problems of diffusion near the surface of the earth and the meteorology of the lower atmosphere.

The work of the Meteorological Department was supervised by the Meteorological Sub-committee of the Chemical Warfare Committee which laid down, in November 1921, the following programme of investigation :—

(*a*) The determination of the effect on vertical and lateral dispersion of gas and particulate clouds of :—

- (i) Type of gas and particulate cloud.
- (ii) Wind velocity.
- (iii) Wind gustiness.
- (iv) Time of day and night.
- (v) Time of year.
- (vi) Temperature gradient.
- (vii) Contour.
- (viii) Other meteorological conditions (*e.g.* state of sky, effect of rain, humidity, etc.)

(*b*) Investigation of meteorological factors which determine the continuity and opacity of smoke screens of various kinds under all the above conditions.

(*c*) Investigation of the qualitative and quantitative behaviour of clouds produced by shell under all the above conditions.

(*d*) Complete investigation of atmospheric turbulence, including its variation with height, and under all possible conditions.

(*e*) Effects of contour (including woods) on air flow.

The staff were faced in 1921 with a practically unexplored field of research, although Taylor, Richardson and Schmidt had made considerable contributions to the mathematical treatment of turbulence. A long series of experiments was begun to determine the crosswind and down-wind variations of smoke concentration, and the mathematical theory was tackled by developing Taylor's concept of a co-efficient of eddy diffusion. Considerable advances were made and many problems clarified, but it had become clear by 1928 that a new approach was required if a solution was to be provided in terms of parameters which could be forecast and measured. A statistical analysis of the problem, combined with certain aerodynamical ideas developed at Gottingen by Prandtl, yielded more promising results and served as a basis for the production of the Service Concentration-Range Slide Rule. This slide rule, which was designed in the Meteorological Department at Porton, enabled concentration calculations to be made in the field from observations of wind velocity and the vertical gradient of wind velocities made on the spot. In practice it was applied during the war to calculating the effective screening length of various types of smoke generators in varying conditions.

In addition to research into the travel and dispersal of gas and smoke clouds, the problem of evaporation was thoroughly investigated as it had a direct bearing on such problems as contamination by mustard gas. The work involved the design and construction of three special wind tunnels in the Meteorological Department. The problem of evaporation from free liquid surfaces was found to

yield to mathematical treatment which could usefully be applied, but the complementary problem of evaporation from unsaturated surfaces proved to be more intractable, as it involved a number of complicated factors such as soil texture and the movement of liquid or vapour within the soil. In spite of this it was possible to produce Persistence Tables which were sufficiently accurate to provide useful estimates for field trials of gas weapons.

Artillery Practice Camps

In addition to data for artillery work at Shoeburyness and Larkhill, artillery 'Meteor' reports had to be provided at the annual practice camps. These commitments were met by attaching a member of the Shoeburyness assistant staff to each practice camp for the season. Normally, four artillery practice camps (Okehampton, Trawsfynydd, Redesdale and Buddon Ness) and one anti-aircraft practice camp (Watchett) had to be catered for. The meteorological office at Larkhill met the needs of the camps on Salisbury Plain and the office at Shoeburyness met those of the Coast Artillery School.

Defended Ports

The question of providing artillery Meteor reports to the artillery units manning the defences of ports at home and abroad was raised by the War Office in June 1929. At that time the list of ports given was as follows :—[1]

Home : Plymouth, Portland, Portsmouth, Dover, Thames and Medway, Harwich, Humber, Tees and Hartlepool, Tyne, Forth, Clyde, Mersey, Milford Haven, Swansea and Cardiff, Belfast, Lough Swilly, Queenstown, Berehaven, Aberdeen.

Abroad : Malta, Hong Kong, Gibraltar, Mauritius, Bermuda, Jamaica, Colombo, Singapore, Aden.

The artillery Meteor reports for a number of the defended ports at home could be provided by Meteorological Office distributive units or observatories already existing, but no convenient centres existed for supplying data to units in the Tyne, Tees and Hartlepool area, the Humber, the Milford Haven, Swansea, Cardiff area, Lough Swilly or Queenstown. The War Office were informed that meteorological staff for stations in those areas would be provided in war by adding an appropriate number of personnel to the establishment of the meteorological section for service with an expeditionary force. A further list of defended ports submitted by the War Office in May 1936 made no mention of the Clyde, Mersey, Aberdeen, Belfast, Swansea or Cardiff, but the remainder were the same as had been specified in 1929.[2] By 1936 the large increase in the number of meteorological offices in operation or contemplated made it clear that there would be no difficulty in supplying the defended ports with Meteor reports without making the special provision visualised in 1929.

The Meteor telegrams to ports overseas were to be provided by the meteorological office in Malta and by the local meteorological services in Hong Kong, Mauritius, Jamaica, Ceylon and Singapore. (This applied also to Penang and Trincomalee which were added to the list in May 1936.) Gibraltar presented some difficulty as the reports were normally required for periods of seven days four times a year only, but it was desirable that the data should be provided by a professional meteorologist as the air around the rock is highly turbulent.

[1] A.M. File S.28446.

[2] A.M. File S.37349/I.

As an investigation of the eddies was then being undertaken a decision was postponed until the results of the investigation were known. The establishment of an office at Aden was on the agenda of the Conference of Empire Meteorologists to be held in London in August 1929, and it was hoped that arrangements might be made to establish an office there capable of meeting the Army's needs. Representations had been made to the Bermuda Government regarding the establishment of a meteorological office, and it was felt that a favourable decision might be hastened if the Army Council would urge the establishment of such an office in the interests of Imperial Defence. The formation of the Bermuda Meteorological Service in 1932 solved the problem of Bermuda but the provision of facilities at Gibraltar and Aden remained under discussion.

The War Office were informed in October 1931 that the investigation of the winds around Gibraltar showed that accurate calibration of the guns would only be possible when the wind was between E. 15° N. and E. 30° S., the direction of firing being towards East or South East and the pilot balloon observations being made from Europa Point. These were the only conditions in which it could be assumed that the winds measured by pilot balloons corresponded to the conditions encountered by the projectile. As the Royal Air Force did not regard the establishment of a meteorological office at Gibraltar as urgent, the cost of one would have to be borne against Army Votes. The problem was finally solved by the establishment of a meteorological office at Gibraltar in October 1935.[1]

The situation at Aden was very similar to that at Gibraltar. A meteorological office was not established after the Conference of Empire Meteorologists, and, in December 1934, the War Office asked for assistance in calibrating certain guns at Aden. In reply, it was suggested that the method of measuring upper winds by observing stannic puffs in a Hills mirror, which was already used by the Royal Air Force at Aden, should be used for the gun calibration. This method apparently sufficed until the emergency meteorological office was opened at Aden in October 1935. When the Meteorological Office staff were withdrawn a year later, their pilot balloon equipment was left for the use of the Army authorities. The Royal Artillery staff were shown how to make the observations of upper wind and how to compute the artillery meteor reports. This arrangement continued until September 1939 when a meteorological office was again established at Aden.

Anti-aircraft Meteor Reports for Air Defence of Great Britain

The War Office first raised the question of the supply of anti-aircraft Meteor reports in the United Kingdom in May 1936 when it was stated that the data should be available to each Group headquarters of the Inner Artillery Zone of the Air Defence of Great Britain (the London area) and to the Local Defence Headquarters in the Thames and Medway area, Birmingham, Leeds, Sheffield and Manchester, as well as to the defended ports already mentioned. A conference, held in May 1936, to consider the Army and R.A.F. war requirements considered that these needs could be met by the outstations of the Meteorological Office without making special arrangements.[2]

[1] A.M. File S.28446.

[2] A.M. File S.37349/I.

The War Office submitted in July 1938 the following further list of gun operations rooms which would require anti-aircraft Meteor reports :—

> London, Chatham, Tilbury, Harwich, Dover, Newcastle, Hull, Middlesbrough, Leeds, Huddersfield, Sheffield, Runcorn, Manchester, Liverpool, Wolverhampton, Birmingham, Coventry, Derby, Portsmouth, Southampton, Portland, Plymouth, Bristol, Newport, Cardiff, Glasgow, Edinburgh, Scapa.

A list of the meteorological offices which would serve each of these was supplied to the War Office. As considerable changes were expected in the War Office List and in the number of meteorological offices available, it was suggested that the list should be resubmitted to the Air Ministry every six months so that the most convenient meteorological office could be allocated in each case. No revised lists as such were submitted by the War Office, but three extra meteorological offices at Tilbury, Enfield and Croydon were suggested as the Army Council felt that one office (Shoeburyness) was inadequate for the London area. Anxiety was also expressed about linking artillery areas as widely separated as Sheffield, Wolverhampton, Coventry and Birmingham to the same meteorological office at Hucknall in Nottinghamshire. The Army Council was informed that Meteor reports for the north and south London areas could be obtained from the Meteorological Office headquarters in Kingsway London, unless it was decided to evacuate that office, and arrangements were made to train the observers at Elmdon Airport, Birmingham, to provide Meteor reports.[1] The situation was improved in the London area in early 1939 by the opening of a meteorological office at H.Q. No. 11 Group at Uxbridge which took over the supply of the Central Forecasting Office to Birmingham in September 1939 provided a centre from which Meteor reports could be obtained in that area, and made the use of Elmdon Airport unnecessary.

In order to ensure uniformity of procedure in the supply of Meteor reports, copies of the Meteorological Office publication No. 317 'The Supply of Meteor Reports to Artillery Units' were distributed to the overseas meteorological services and home stations concerned. The sections of the publication dealing with anti-aircraft Meteor reports were obsolete by 1938, and in October of that year a duplicated supplement to the publication, setting out the modern method, was distributed to holders of the original publications.

The Expeditionary Force

The provision of meteorological facilities for an expeditionary force was first considered in 1921 when the Air Ministry informed the War Office that as the peace requirements of the War Office were being satisfactorily met, the Air Council were in a position to consider the meteorological organisation which would be required in the event of war. In reply, the War Office stated their requirements for :—

(*a*) a small war in which six infantry and one cavalry division were employed ;

(*b*) a great war in which twenty infantry and two cavalry divisions were employed.

[1] A.M. File S.28446.

The Meteorological Office prepared a detailed scheme to meet the combined needs of the Army and Royal Air Force for a small war, in which it was visualised that eight R.A.F. squadrons would be employed. The scheme involved the provision of 23 officers and 122 men of whom 7 officers and 37 men would proceed overseas with the first contingent. The Army Council approved the proposals in May 1924.[1] The Meteorological Office stated that the scheme included only the skeleton requirements of a great war and could be enlarged as necessary to meet such requirements. It was subsequently pointed out to the War Office that the scheme did not provide for the dispatch of meteorological personnel for operations which did not involve mobilisation, a limitation which the War Office accepted. The Treasury approved the enrolment of personnel for the first contingent of 7 officers and 37 men. The War Office expressed their agreement with this decision.[2]

In view of the Government decision that military preparations for a major war were not to be undertaken for ten years, the scheme remained substantially unchanged until the end of 1935. The 6th meeting of the Sub-Committee (of the Committee of Imperial Defence) on Air Defence Research, however, agreed that the Air Ministry, together with the Admiralty and War Office, should prepare a scheme for providing and training reserves to meet war requirements. The arrangements in force for training personnel for the naval meteorological service were considered adequate to meet naval requirements in the event of war, but the whole problem of the meteorological service for an expeditionary force had to be reconsidered.

War Office and Air Ministry representatives met in May 1936 to consider the problem on the basis of an Expeditionary Force consisting of the following components :—

Army : (*a*) Two Corps.
(*b*) Two Sound Ranging Sections.
(*c*) Base Organisation.

R.A.F. : (*a*) One Group associated with the Field Force.
(*b*) An Air Striking Force of two Groups.
(*c*) An Advanced Air Defence Force.

It was assumed that in the initial stages, the Army and Royal Air Force would share a General Headquarters. The Conference decided that the following meteorological organisation would be needed :—

Six full forecasting sections. (Type 1 or 2) at :—

G.H.Q.	R.A.F. Group H.Q.
Corps I H.Q.	Air Striking Force H.Q.
Corps II H.Q.	Advance Air Defence Force H.Q.

Two Meteorological units with Meteorological Officers in charge :—
One with each of the two Sound Ranging Sections.

Six Mobile pilot balloon sections :—
Three in the main war area.
Three with the Air Striking Force.

[1] A.M. File S.17887.
[2] A.M. File S.37349.

Eight 'Wind and Weather' observing posts :—
Distributed as required throughout the war area.

Specialist Meteorological Officers :—
Gas, Artillery, Investigation and Liaison Meteorological advisers attached to Air Striking Force Group H.Q.s.

Reserve :—
A small reserve to be maintained at the Base and on the lines of communications.

The staff required to implement the proposals were 35 officers and 136 men. The Treasury approved the proposals, including those involving establishments, in January 1937.[1]

The Air Ministry informed the War Office in June 1936 that the provision made for gas warfare could only be regarded as a nucleus to study the problem and prepare for enemy action. If circumstances necessitated the offensive use of gas, a considerable number of additional officers and men would be required. The War Office then emphasised the importance of the additional personnel being available in peace, as the subject was highly specialised and no ready-made recruits were available outside the Meteorological Office. It was suggested that in view of the responsibilities involved, a meteorological officer of the rank of Flight Lieutenant should be on the establishment of G.H.Q. and at the headquarters of each Corps for Gas Duties, and that three of the Flying Officer posts should be upgraded accordingly. It was also stated that four mobile observing units, each manned by one Flying Officer and one N.C.O. should be available for each Corps.[2] The Air Ministry agreed with these requirements in January 1937 but stated that they would be left in abeyance until the main proposals had been implemented, as the availability of personnel was likely to prove the major difficulty. The War Office requirements were further modified in February 1938 when it was decided that the duties of the mobile observing units would be performed by trained Army personnel and need not, therefore, be provided for by the Air Ministry.

A complete review of the meteorological facilities for the Army was needed by June 1939 and a further conference to review the whole question was suggested to the War Office. The following items, *inter alia*, were suggested for the agenda :—

(*a*) The meteorological contingent required to accompany the Field Force : its composition and responsibilities.

(*b*) The meteorological duties to be performed by Army units in connection with smoke screens and chemical warfare, and the relationship of these units to Meteorological Office personnel.

(*c*) The provision of a mobile laboratory for use in chemical operations, and the attachment of meteorologists to such a laboratory.

(*d*) The specialised training of Meteorological Office personnel for ballistics, chemical warfare, sound-ranging and tactical requirements.

[1] A.M. File S.32863.
[2] A.M. File S.37349.

(*e*) The training of Army personnel in meteorology, including Army officers generally and officers and men required for the duties mentioned in (*b*) above.

(*f*) The preparation of instructional books for meteorological personnel co-operating with the Army and for Army personnel.

The War Office agreed in August 1939 to a further conference, but war had broken out before it could be held.

Personnel

The crux of the problem of providing a meteorological service for an Expeditionary Force was the question of personnel—their recruitment, training and conditions of service. In this connection, three points were of outstanding importance :—

(*a*) The Meteorological Office is a civilian organisation.

(*b*) In the United Kingdom trained meteorologists were practically non-existent outside the staff of the Meteorological Office. A sound knowledge of mathematics and physics, although an essential qualification for a forecaster, is not enough as meteorology is still to a considerable extent an empirical science and considerable training and experience is necessary before a man can be regarded as a competent forecaster.

(*c*) The Meteorological Service for the Expeditionary Force was classed as a reserve organisation, but it differed radically from other reserve bodies in that it was not a reinforcement for an already existing organisation, but was itself the only field meteorological organisation.

When the first proposals for a meteorological service in the field were being worked out in 1922, the Air Ministry Staff ruled that it should be a reserve service of the Royal Air Force, and that this R.A.F. meteorological service should also provide for the needs of the Army. It was proposed that the 23 officers and 122 men should be recruited into the normal R.A.F. Reserve and that the 7 officers and 37 men required for the first contingent should be asked to volunteer to join up if required before the formal proclamation of mobilisation.

It was found that in practice the scheme presented certain difficulties, the chief being that of obtaining enough volunteers on the terms offered and those connected with the special liability of the men required for the first contingent.[1] Discussion of these questions continued from 1923 until 1936 and at no time during that period was it possible to fill even the limited establishment of 7 officers and 37 men. Although this situation could be tolerated while the Government's ten-year rule was in force it was clearly highly unsatisfactory. The precarious state of the meteorological service in the field was emphasised by the Abyssinian crisis when the Meteorological Office was asked to send three units in uniform to the Middle East to be ready in case of hostilities. Although there were enough officers and men in the Meteorological Reserve, there was no power to muster them. Volunteers were called for, but the Treasury stated that it was in no position to give a ruling on whether civil or R.A.F. pay would be offered.[2] Eventually, civilian units were sent and, although the R.A.F. units to which they were attached gave them all possible

[1] A.M. Files S.17887 and S.32863.

[2] A.M. File S.36416.

assistance, many difficulties arose. The position of the personnel if war had broken out was also far from clear. As civilians taking part in active war operations, they would have been in a very invidious position.

Although the crisis of 1935 underlined the weakness of the position, little or no progress was made in the next two or three years. In fact, the situation worsened as an increased establishment of 35 officers and 136 other ranks was agreed in May 1936. In April 1937, the D.M.O. put forward three possible solutions to the problem and pointed out the weakness of each. The proposed solutions were :—[1]

(*a*) A Meteorological Reserve composed of members of the Meteorological Office staff and members of the general public, *i.e.*, the policy which had been adopted up to then. The weaknesses of this scheme were the facts that few of the Meteorological Office staff were prepared to volunteer, leaving about two-thirds of the vacancies to be filled from outside, and that the rules of the Reserve allowed for only a fortnight's training annually, whereas D.M.O. estimated that at least one year's intensive training would be needed before a suitably qualified member of the general public could be considered competent to serve as a meteorologist with the Expeditionary Force.

(*b*) A reserve composed of professional meteorologists. This proposal, which dealt with officers only, involved adding the personnel required for the Expeditionary Force to the peace-time establishment of the Meteorological Office, earmarking them for war duties and specialised training. D.M.O. considered that the additional staff could be fully employed in peace-time on the study of meteorological problems in warfare, the necessity for which had been emphasised by the Committee of Imperial Defence, in providing facilities for R.A.F. exercises and Army practice camps, and in making the administrative Staff for the meteorological sections which would accompany the Field Force. The addition of these posts to the establishment of the Meteorological Office, however, would throw the establishment out of balance, and reduce the prospects of promotion and a satisfactory career in the Meteorological Office to such an extent that the scientific quality of the staff as a whole would be adversely affected, the better graduates being unlikely to enter the Office. It would also be difficult to induce the staff to volunteer on the terms offered as there were none of the normal inducements such as learning to fly and the staff would be spending a fortnight of their holiday each year performing their normal duties. For a number of reasons, D.M.O. rejected the proposal to compel a candidate for entry into the Meteorological Office to undertake to join the Reserve.

(*c*) Meteorologists as regular R.A.F. officers. This proposal was designed to overcome some of the difficulties of the other proposals, such as mustering and moving the meteorological sections before mobilisation had been proclaimed, imposing military liability on civil servants and promotion prospects. It was suggested that a number of suitably qualified men should be recruited direct into the R.A.F. and trained as meteorologists. They would become R.A.F. specialists and look to the R.A.F. for their career.

[1] A.M. File S.32863/I.

(*d*) Other Ranks. This problem was complicated by the fact that the duties assigned to the 'other ranks' in the Meteorological Reserve were performed in the Meteorological Office by technical assistants, grades I, II and III, whose eductional qualifications and social status was above the normal in the equivalent R.A.F. ranks of warrant officer, sergeant and corporal. The pay of the technical assistants grades I and II, was also considerably higher than their R.A.F. equivalents. D.M.O. was unable to suggest a satisfactory solution in the case of the warrant officers and sergeants but proposed to fill the corporal posts from the number of 'observers' in the Meteorological Office. The observer grade consisted of ex-airmen, mostly with reserve liabilities, and although the grade had become obsolete, there were still about 80 observers in the Meteorological Office staff. He proposed to fill the L.A.C. establishment by training a number of regular airmen in meteorological work during their last year of service and enrolling them in the Meteorological Reserve for their reserve service.

These problems were fully discussed by the Air Ministry departments concerned, but little progress had been made when, in December 1937, the staff problem was radically altered by the decision that in war the meteorological offices on Operational War Stations and War Training Stations should provide a 24-hour service for seven days a week. Until then it had been assumed that the peace-time staff would be adequate to meet the home requirements of the R.A.F. in war, at least in the initial stages, but the new policy involved the provision of 64 officers and 238 assistants additional to the peace-time staff. As these men would be serving at home they could be civilians. In May 1938, D.M.O. proposed to meet the new situation, and at the same time provide an adequate number of skilled meteorologists for service with the Expeditionary Force, by organising training centres in a number of large towns to train civilians in meteorology.[1] As these men would be available in war to dilute the permanent staff in the United Kingdom, D.M.O. considered that all the officers required for the Expeditionary Force could be drawn from the professional staff of the Meteorological Office. He suggested that one half of the number should consist of volunteers from the Meteorological Office in the R.A.F. Meteorological Reserve, while the other half should consist of members of the Meteorological Office staff who would be seconded to the R.A.F. in peace-time and granted five-year commissions. This latter body of officers would then be available to form such units as were required in advance of mobilisation.

There were a number of staff and financial difficulties inherent in these proposals and it was decided to organise the training scheme within the framework of the R.A.F.V.R. and to transfer to the R.A.F.V.R. the eleven meteorological officers who were then serving in the R.A.F. Reserve. It was felt that the pre-mobilisation difficulties could be overcome by amending the contracts of the permanent civil staff to provide for service overseas where required. The proposed establishment of the Meteorological Section of the R.A.F.V.R. was 125 officers and 340 other ranks, enough to meet the needs of the Expeditionary Force and the additional requirements of the R.A.F. at home in war-time. The Treasury approved the proposals in April 1939 with the proviso that there should be a limitation of 24 days on the amount of training,

[1] A.M. File S.32863.

including obligatory training, undertaken in any one year.[1] Arrangements were then made to bring the administration of the scheme under the auspices of Reserve Command. A member of the permanent Meteorological Office staff was appointed to the rank of wing commander and attached to Reserve Command to collaborate in all matters affecting the recruitment and general administration of the Meteorological Section of the R.A.F.V.R. Preliminary arrangements were made to form a panel of lecturers, publicity was prepared and a search for suitable accommodation begun. Delays occurred in obtaining accommodation and in arranging suitable evenings and hours for classes. These matters were still being discussed and the training scheme had not been started when war broke out. On mobilisation, only the former members of the R.A.F. Meteorological Reserve were available, making a total strength of 7 officers and 22 other ranks to fill a total establishment of 30 officers and 124 other ranks.

Equipment

The meteorological equipment provided for the meteorological units with the Expeditionary Force was essentially the same as that issued to the corresponding stations at home, the most noteworthy items being Dines pressure-tube anemometers for H.Q. R.A.F. Component Field Force and H.Q. A.A.S.F. Detailed schedules of the general and meteorological equipment required by each meteorological unit were prepared in November 1937 and included in the R.A.F. war equipment schedules used by the authorities responsible for assembling mobilisation stores. Arrangements were also made to provide the necessary transport, viz., one three-ton tender each for H.Q. R.A.F. Component Field Force and H.Q. A.A.S.F. It was proposed that the stores for all the meteorological units including the units with Army Corps H.Q. should be taken to the two main headquarters first, and be redistributed from there.[2]

Two alternative arrangements for the mobile units were considered. At first it was proposed that these should consist of a three-ton tender and a modified office trailer, but it was later suggested that a self-contained office tender would be more suitable. Owing to delay in providing these vehicles, however, the meteorological prototype was not delivered to the Meteorological Office until August 1939. Further modifications to adapt the office tender for meteorological work were undertaken but war broke out before these were completed.

Communications

The communication facilities required by the meteorological service in the field were set out in a memorandum prepared by the Meteorological Office in December 1937.[3] For the Field Force, it was considered that direct teleprinter links, reserved for meteorological traffic, should be provided from the Meteorological Office, London, and the headquarters of the French Meteorological Office, to the meteorological unit at General Headquarters. It was suggested that teleprinter links or direct telephone lines, solely for meteorological work, should also be provided from General Headquarters to the three meteorological units at Corps and Group Headquarters ; teleprinters so linked that the reports

[1] A.M. File S.32863.
[2] A.M. File S.26870.
[3] A.M. File S.43281.

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from London could be received simultaneously at G.H.Q. and at the three sub-offices were suggested as the ideal arrangement. For the A.A.S.F. a direct meteorological teleprinter link with the Meteorological Office, London, or with G.H.Q. was requested.

Air Ministry and War Office representatives discussed the memorandum in March 1938. The traffic from the Meteorological Office to the several forecasting sections was estimated at 2,500 groups four times per day at the intermediate synoptic hours. On this basis it was thought that the traffic to G.H.Q. could be dealt with in the general communication system already visualised, but that another channel would have to be provided to H.Q. A.A.S.F. It was doubted whether the communications which had been planned between G.H.Q. and Corps H.Q. would be adequate to carry the meteorological traffic, a point which does not appear to have been finally clarified.[1]

Communication with the mobile units was also considered, and it was agreed that as the units would normally be in the vicinity of a service headquarters, normal channels of communication could be used. It was also considered that normal service channels could be used for distributing meteorological forecasts and reports to service units. It was visualised that the forecasts would be issued by teleprinter four times daily and amplified as necessary by telephone conversation. Landline communication was stipulated in all cases, for reasons of security, except for artillery Meteor reports. The War Office insisted that these reports should be issued in clear by wireless if necessary, and, as they would be based on local data from the vicinity of the front line, this exception to the general policy was agreed.

The above scheme remained in force until the outbreak of war, with the exception that an additional direct line between H.Q. A.A.S.F. and the headquarters of the French Meteorological Office was requested in September 1938. In practice, however, considerable difficulties arose owing to a shortage of cross-Channel lines and an apparent misunderstanding between the Air Ministry and the War Office regarding the responsibility for the provision of the meteorological teleprinter lines. During the crisis of September 1938 it was found that no meteorological channel had been provided between the Meteorological Office and H.Q. A.A.S.F., and D.M.O. agreed that, provisionally, an effort would be made to supply a certain amount of data from Paris if a direct line could be provided to the latter place. By August 1939 a direct line to H.Q. A.A.S.F. had still not been provided. An assurance was received that the line would be provided, but this was later found to be incorrect, and for some weeks after the outbreak of war the meteorological section at H.Q. A.A.S.F. had to operate without adequate means of obtaining synoptic data.[2]

In addition to the land-line facilities, arrangements were made for the provision of two wireless receiving trailers, one for H.Q. R.A.F. Component, Field Force and one for H.Q. A.A.S.F. These trailers, which were pulled by the three-ton tenders containing the stores for the meteorological sections, were intended to pick up the broadcasts of meteorological data which might be continued by neutral countries. Copies of the British meteorological cyphers were also provided for use in receiving or transmitting data in the event of land-line failure.

[1] A.M. File S.37349/I. [2] A.M. File S.43281.

Civil Aviation

The Meteorological Office plans to meet the needs of Civil Aviation in war were based on the National Air Communication scheme described in a draft Appreciation on the Employment of Civil Aviation in War written by the Director-General of Civil Aviation in October 1938, and on a memorandum prepared for the Inter-Departmental Committee on International Air Communications in January 1939.[1] The proposals put forward in these two papers received Air Staff approval in January 1939 and were forwarded to the Meteorological Office for action on the meteorological aspects. The scheme envisaged three area control stations, at Bristol, Speke and Renfrew, bases for overseas and continental flights at Pembroke, Exeter, Poole, Shoreham and Perth, advanced landing grounds at Heston and Aldenham and a number of bases under the area control stations for internal flights, *viz.* Barnstaple, Weston-super-Mare, Cardiff and Jersey under Bristol, Ronaldsway and Barton under Speke and Aberdeen under Renfrew. Belfast was also scheduled as an airfield and customs examination centre.[2]

Commenting on the Meteorological Office proposals to meet these requirements, the Director-General of Civil Aviation's department suggested that no provision need be made for Barnstaple and Aberdeen, as these bases could be served by telephone from Bristol and Perth respectively. It was also suggested that Heston and Aldenham could obtain the meteorological information which they required from the meteorological office at H.Q. Fighter Command, and that the observing duties at these places could be undertaken by the Air Traffic Control Officers. Aberdeen was deleted from the list of N.A.C. stations in August 1939. Otherwise, the modified proposals remained in force until the outbreak of war.

The question of the meteorological organisation on overseas routes which would be used by civil aircraft on N.A.C. duties in war was raised in July 1939 by the Directorate of Civil Aviation, who were assured that existing meteorological facilities would be maintained as far as practicable and that arrangements had been made with the French meteorological service to ensure adequate meteorological facilities for routes across France and along the West African routes.[3]

In peace-time, it was the usual procedure for civil aircraft while still airborne to obtain by wireless both forecasts and reports of weather conditions at their destination. Under war conditions it was proposed to reduce wireless traffic to and from aircraft to a minimum, and, in particular, to eliminate as far as possible meteorological messages to aircraft, as the codes carried by aircraft would be necessarily simple and would not provide sufficient protection for meteorological messages. The war-time procedure recommended was that normally the pilots should obtain all relevant information before take-off. If it was found that the development of the actual conditions varied sufficiently from the forecast conditions to warrant the transmission of a message to the aircraft, the message would take the form of a navigational instruction and not of a meteorological report, *e.g.* the pilot would be instructed to fly at a different height or on a different course. It was considered, however, that there would be a number of occasions when it would be essential to transmit meteorological

[1] A.M. File S.49258. [2] A.M. File S.43835/I.
[3] A.M. File S.54980.

information, and for this purpose a special code was prepared for the use of civil pilots. It was a meteorological extract from the Air Force Code, but for civil aviation it was proposed to use it without a recoding device. As in this form it was a simple substitution cypher, its strength was very slight and it was provided for use only in cases of near-emergency. In a genuine emergency information could be issued in clear at the discretion of the controller.

Government Departments and Public Services

In peace-time, the meteorological forecasts, warnings and other information issued by the Meteorological Office were used by a large number of Government Departments and Public Services. Although it was proposed to discontinue the issue of meteorological information to the public in war, it was considered that in the interests of national efficiency certain of these recipients should continue to receive meteorological information under suitable safeguards.

The Home Office, Board of Trade, Ministry of Agriculture and Fisheries and Ministry of Transport were informed in June 1938 that as it was of the utmost importance that meteorological information should be withheld from the enemy, all possible steps would be taken to prevent any weather reports or forecasts from falling into the hands of unauthorised persons. For that reason, the transmission of meteorological information by wireless telegraphy or radio-telephony, and the publication of forecasts in the newspapers, would cease in an emergency. The Departments were asked to examine the question and inform the Air Ministry of services for which the receipt of meteorological information was essential. Similar instructions were sent in August 1938 to the General Post Office, Central Electricity Board, Forestry Commission, Port of London Authority, Fishery Board for Scotland, Trinity House and the Commissioners of Northern Lighthouses.[1]

In reply, the Ministry of Agriculture and Fisheries, the Ministry of Transport, the General Post Office, the Forestry Commission, the Port of London Authority, Trinity House and the Commissioners of Northern Lighthouses stated that they wished for no special arrangements to be made, although the Ministry of Agriculture and Fisheries qualified their statement by assuming that fishermen or farmers could apply to be placed on the distribution list if necessary, and the Commissioners of Northern Lighthouses considered that it would be an advantage, although not essential, if the masters of their vessels could receive gale warnings. Requests for information after the outbreak of war indicated that in some instances full consideration may not have been given to the problem before negative replies were sent. The Home Office asked only that two copies of the forecasts (presumably the Daily Weather Report) should be sent to the Under-Secretary, the Central Electricity Board stated that forecasts would be essential for their seven control centres and the Board of Trade and the Fishery Board for Scotland emphasised the importance of forecasts and warnings to ships and fishing vessels. They suggested the supply of forecasts through the naval routeing officers or fishery officers while the vessels were in port. The Department of Agriculture for Scotland suggested that forecasts of rain during the harvest and lambing seasons would be of great importance. Acting on these replies, arrangements were made to send two copies of the Daily Weather Report to the Home Office, and to pass forecasts and warnings

[1] A.M. File S.36727.

to the London headquarters of the Central Electricity Board, for transmission to the regional centres affected, if this was considered necessary. The question of supply of forecasts and warning to vessels in port was taken up with the Admiralty, and it was agreed that the distribution should be made through the Naval Control Service Staffs. It was not found possible, however, to agree to a Board of Trade request that visual gale warnings should continue to be hoisted in time of war.

Preparations for the Evacuation of the Meteorological Office

Hurried preparations were made during the pre-Munich crisis of 1938 for the evacuation of the Meteorological Office Headquarters in accordance with the general policy and arrangements in force at that time. In war, a forecasting and signals centre was to be set up at Dunstable, while the remainder of the organisation was to be moved to ' Zeta ' in the Southport area. Estimates of the material to be moved and of the floor space required were prepared, and preliminary arrangements were made for moving the store of instruments and the most valuable part of the Meteorological Office Library from their peace-time location in South Kensington.[1]

The policy regarding evacuation was changed in February 1939, and it was no longer considered that the evacuation of the administrative branches would be inevitable or automatic. At about that time, the proposed evacuation headquarters of the Meteorological Office were changed to Tetbury. In fact, none of the Meteorological Office divisions, other than the Forecasting Division, was evacuated in September 1939, but it was later decided to move the Marine, Climatological and Instruments Divisions and the Library to Wycliffe College, in Stonehouse, near Stroud, as the accommodation they occupied in South Kensington was required for other purposes. The move was made at the end of November 1939.

Accommodation had also been sought early in 1939 for the Meteorological Office Training School which it was proposed to expand considerably to deal with the large intake of recruits that would be required if war should break out before the Meteorological Section of the R.A.F.V.R. could be organised and trained. Property was requisitioned in Southport for this purpose, as it was desirable to have the Training School near the Administration headquarters of the Meteorological Office. When it was decided that the latter should go to the Tetbury area it was at first proposed to leave the Training School at Southport, in view of the difficulty of finding alternative accommodation, but this was later allocated at Stroud. Accommodation was also earmarked in London at Berkeley Square House for use if evacuation did not take place, and it was here that the Training School moved on the outbreak of war.[2]

[1] A.M. File S.47611. [2] A.M. File S.59938.

CHAPTER 2

COLLECTION AND DISSEMINATION OF DATA

Teleprinter Network

First class communications are of prime importance in developing an efficient meteorological service, as a large volume of reports and other traffic have to be handled with the utmost speed, and it was clear in 1935 that the existing facilities would eventually prove inadequate in peace and would certainly be impracticable in war. Reports of actual conditions and forecasts were distributed to R.A.F. and civil stations by a series of collective wireless broadcasts and by the Borough Hill radio-telephony station. The frequency and number of the reports broadcast by the latter station were being increased as the R.A.F. expanded and night flying developed, and it was clear that saturation point would be reached before the R.A.F. expansion was completed. The fact that the radio-telephony broadcasts would have to cease in war was another important factor to be considered. It became obvious that only something in the nature of a teleprinter network could handle the traffic in peace-time and provide the necessary speed and security in war.

The possibilities of a meteorological teleprinter network were discussed in February 1935 by representatives of the Directorate of Signals and the Meteorological Office who considered that such a scheme was practicable. The D.M.O. then forwarded to the Directorate of Signals detailed proposals which were based on the 1935 Meteorological Office scheme for fourteen group centres with Type A meteorological offices, each Type 'A' office being in communication with a number of subsidiary Type 'B,' 'C' and 'D' offices. It was suggested that teleprinter connection should be provided between the Meteorological Office, London, and each group centre, and between each group centre and its subsidiary offices.[1]

In consultation with the G.P.O., a plan was evolved in November 1935 which would provide the following facilities at an annual rental for lines and apparatus of approximately £26,000 :—

(*a*) A simultaneous broadcast transmission to all 'A' offices from one teleprinter at Air Ministry.

(*b*) Two, three or four partial broadcasts to 'A' offices, depending on the number of teleprinters at Air Ministry.

(*c*) Transmission of messages between Air Ministry and any one of the 'A' offices, the number of separate transmissions possible simultaneously being governed only by the number of teleprinters available at Air Ministry.

(*d*) Broadcast transmissions from each 'A' office to its subsidiary 'B,' 'C' and 'D' offices, but no separate transmissions to any one subsidiary.

(*e*) Simultaneous communications between 'B,' 'C' and 'D' offices and their corresponding 'A' parent office.

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[1] A.M. File S.35480.

In submitting these proposals to the Meteorological Office, the Directorate of Signals suggested that before the scheme was finally agreed, a trial should be carried out involving only two ' A ' offices and their respective sub-offices.

In the meantime, the revised Meteorological Office proposals to meet Expansion Scheme ' C ' had been elaborated and it was agreed in 1936 that the Directorate of Signals would make the necessary arrangements regarding changes in communications. The provision of the teleprinters was left in abeyance during 1936 while the details of the Meteorological Office reorganisation were being thrashed out, but the problem of collecting the hourly reports for the Borough Hill broadcasts was becoming more pressing as new offices were opened and the number of reports increased. It was decided that the first teleprinters to be provided should be those from the Meteorological Office to the twelve centres at which reports for the Borough Hill broadcasts were collected, and a provisional schedule was prepared to permit the collection in London of reports from 72 airfields within eight minutes of the time of observation. This scheme, which was to form the nucleus of the whole meteorological teleprinter system, was approved by C.A.S.[1] Treasury approval was received in August 1937 and by the beginning of October 1937 all the centres except Abbotsinch had been connected by direct teleprinter to the Meteorological Office.

As the teleprinters at the outstations would be in use only for a short period each hour for transmitting reports (for the remainder of the time they would be receiving), it was unnecessary to employ fully qualified operators for that purpose, and D.M.O. agreed that certain members of the Meteorological Office staff should receive sufficient training to enable them to transmit messages by teleprinter. Arrangements were made in September 1937 for a fully qualified Post Office teleprinter operator to be loaned to the Air Ministry to act as supervisor in the Meteorological Office teleprinter room and to train the meteorological staff in the use of the instruments. During the latter half of September the telephone-typists from the meteorological centres concerned were trained in this way. The training course lasted normally about one week, five or six operators being trained in each course.

From the end of 1937 onwards, the main meteorological teleprinter network was gradually built up as new offices opened, the main limiting factors being the availability of land-lines and the supply of teleprinters. As far as possible, the meteorological network was made to correspond to the R.A.F. grouping of stations, *i.e.*, the meteorological teleprinter group centres were sited at R.A.F. Group headquarters, and the meteorological offices on R.A.F. stations were connected by teleprinter to the meteorological teleprinter centre at the R.A.F. Group H.Q. which controlled the stations. This layout simplified the arrangements for providing co-ordinated meteorological advice to the R.A.F. at the Group H.Q. and the stations under their control. For geographical and other reasons, there were a number of exceptions to this general rule, notably in the case of the widely scattered Coastal Command stations, some of which were connected to the most convenient teleprinter centre. A teleprinter centre was opened at Norwich in anticipation of the opening of an R.A.F. Group H.Q. there, and its associated forecasting centre continued to serve a number of stations in the vicinity, although the R.A.F. Group H.Q. moved elsewhere. The meteorological offices at Command H.Q. were normally

[1] A.M. File S.35480.

connected by separate lines to the main Air Ministry meteorological teleprinter centre and had no direct communications with their Group H.Q.s. If the normal R.A.F. chain of communication from station through Group H.Q. and Command H.Q. to Air Ministry had been adopted, it would have created an unworkable bottleneck in the collection of reports. The number of stations on the meteorological teleprinter network increased from 20 in October 1938 to 48 in September 1939.[1]

Emergency Communications Centre

During the pre-war development of the meteorological teleprinter system, the main centre of the network was situated in the headquarters of the Meteorological Office in London. Although this arrangement was convenient in peace-time, it had obvious disadvantages in the event of war, as the whole system would be dislocated if the main centre were put out of action. The provision of a meteorological signals centre outside London was considered in July 1937 by D.M.O. and D. of S. who agreed that the centre might be located in the neighbourhood of the main Royal Air Force Central Exchange, and that, in addition to being the teleprinter centre, it should include the wireless transmitting and receiving facilities required by the Meteorological Office. The D. of S. suggested in January 1938 that the centre should be located near Manchester instead of near Leighton Buzzard, on the grounds that many of the lines from Leighton Buzzard would still run through London and that the provision of land-lines from Manchester would be much cheaper. D.M.O. expressed serious misgivings at this suggestion in view of the danger of air attack, and the matter was referred to D.D.Ops. who advised against the Manchester site.[2]

The situation was changed a few months later when the Admiralty, War Office and Air Ministry agreed to develop a combined system of teleprinter channel working for their land-line communications. As the meteorological circuits could be incorporated in the channel system, it was agreed that a centre in the vicinity of Leighton Buzzard would be most suitable. The proposal was approved, and in November 1938 a suitable site was found on the outskirts of Dunstable. Action was taken at once to acquire the site, and Treasury approval was received in May 1939.[3]

In January 1938, D.M.O. had stated that he proposed to transfer the greater part of the work of the headquarters forecasting unit to the new communications centre as a permanent arrangement but when the matter was reviewed in September 1938, it was decided that the inconvenience and loss of technical and administrative control and contact involved in such a scheme was undesirable. Instead, it was decided to provide accommodation on the site for the forecasting unit in case evacuation was ordered, but that until that time, the forecasting unit would remain in London.[4]

Progress on the site was slow and the possibility of moving the centre to Gloucester, the proposed evacuation area for the Meteorological Office headquarters, was considered, but rejected in July 1939, when it was decided

[1] *See* Appendix 4 for a graph showing the variation of the total number of stations connected to the Central Forecasting Office (ETA) prior to and during the war. A.M. File A.801406/45.

[2] A.M. File S.36836. [3] A.M. File S.45519. [4] A.M. File S.36836.

that temporary buildings should be erected at Dunstable in the first place in order to hasten the completion of the centre. Even this did not have the desired effect, however, and as the international situation deteriorated during August, a temporary centre was prepared in Birmingham. On 23 August the Cabinet decided that the forecast and signals centre should be evacuated. The move to Birmingham was made during the following two days and by 2100 hours on 25 August, the Birmingham centre was operating as the main meteorological teleprinter centre. The Dunstable site was not finally ready for occupation until the beginning of February 1940.[1]

Telegraphic Reporting Stations in the United Kingdom

For the preparation of the weather charts on which forecasts are based, the Meteorological Office relies upon a series of synchronous observations made normally at three-hourly intervals at a network of stations in the United Kingdom and overseas. The hours of observation, fixed by international agreement, are known as 'synoptic hours' and the observing stations as 'synoptic reporting stations.' The network of stations in each country is chosen to give as representative and comprehensive a picture of the weather conditions as possible. In the United Kingdom, airfields at which meteorological staff are employed are chosen as synoptic stations whenever practicable, but very few of these are situated on the coast. Coastal stations are an important part of the network as they not only extend the area of observation from ground stations as far as possible, but in many cases they give the first indication of impending changes. In order to obtain coastal observations the practice is to provide instruments to certain selected lighthouses, coastguard stations and Admiralty signal stations at which the staff have agreed to make the observations and dispatch the reports for a small renumeration. Before the war, the reports were usually dispatched by priority telegram, and these stations were known as 'telegraphic reporting stations.'

It was considered very important that the telegraphic reporting stations should continue to function without interruption in the event of war, and, as the great majority of the personnel were naval reservists, the Air Council pointed out in May 1938 to the Admiralty, Board of Trade, Trinity House and Northern Lighthouse Board the importance of the reports being continued.

Assurances were given that no difficulties were expected as it was not proposed to move the personnel of these stations in the event of mobilisation.[2] The case of the Bell Rock Lighthouse, however, was complicated by the fact that the only rapid means of communication with the mainland was by radio telephone. At first it was proposed to issue a secret code to the lighthouse keeper for the transmission of meteorological reports as these reports were particularly valuable for forecasting conditions over the North Sea, but when the general question of the desirability of lighthouses transmitting weather reports by wireless in war-time was raised by the New Zealand Government, the matter was referred to the Admiralty in June 1939. The Admiralty replied that they wished to discourage any practice which might prejudice the non-belligerent status of lighthouses, or would raise a suspicion that they were being used for intelligence purposes. They therefore considered that no meteorological

[1] A.M. File S.56428.

[2] A.M. Files S.36727 and S.42779.

reports should be sent from the Bell Rock in war-time until the cable communication, which they proposed to instal, was available. The Board of Trade was accordingly informed that in the event of war, reports from the Bell Rock would be discontinued until land-line communication had been installed.

The question of supplementing the existing network of reporting stations in wartime by opening new observing stations was raised in May 1939 when it was suggested that observing stations would be most useful in the following areas which were the most serious gaps in the network: North Devon; West Wales; Cumberland Coast: Gloucestershire, Worcestershire, Shropshire; North West Scotland.[1] Futher action on the matter was delayed by the consideration of more pressing problems and the question was not reopened until October 1939.

Overseas Reports

Arrangements with the Dominions and Colonies

One of the main suggestions regarding meteorological war organisation which the Admiralty made in October 1935 was that an interservice and interdepartmental conference should be held to co-ordinate the war requirements of the Services, and that the meteorological services of the British Commonwealth should be informed of those requirements and requested to co-operate.

Little progress was made with this problem until May 1938 when a conference, at which the Admiralty and the Dominions, Colonial and India Offices were represented, discussed methods of approaching the Dominions Governments.[2] It was agreed that a general memorandum on the subject should be prepared in the Meteorological Office and circulated to the various Governments by the Dominions, Colonial and India Offices, with suitable covering letters pointing out the desirability of making similar arrangements to those being made in the United Kingdom, and offering assistance if required. The exact method of approach in individual cases was to be left to the Offices concerned. The memorandum was forwarded to the Dominions, Colonial and India Offices in August 1938. Specific points which were not appropriate to the general memorandum were dealt with in the covering letters. The memorandum described broadly the requirements of the Services in war, the probable dislocation of the international exchange of reports in war, the methods which were being adopted by the Meteorological Office to obtain as much data as possible, and the precautions which would be adopted to prevent the enemy from obtaining meteorological information from the areas covered by the Meteorological Office organisation.

The most important question raised in the covering letter to the Dominions Office was the method of obtaining reports from Canada and the United States in the event of war. In peace-time, the European Meteorological services relied upon the broadcasts of these reports made by two powerful transmitters at Arlington and Annapolis in the United States. In the event of war it was clearly desirable that both the Canadian and the United States reports should be withheld from the enemy, but it was equally important that the reports should reach Great Britain and her Allies. It was recognised that the matter could not be pursued with the United States before an emergency arose, and it was not known whether the United States would continue to broadcast

[1] A.M. File S.53679.

[2] A.M. File S.42779.

her own reports or suppress them if she remained neutral. The possible need to withhold Canadian reports from the United States was mentioned, although this would create a very difficult situation for both countries. The transmission of the Canadian reports to the United Kingdom by cable or, alternatively, in secret code from the wireless transmitter which was being erected in Newfoundland in connection with the transatlantic air service, was suggested as an alternative to the Arlington and Annapolis broadcasts. The Dominions Office was asked to bring these problems to the notice of the Canadian Government.

In reply, the Dominions and Colonies listed the reports which they would require in war-time, and Australia, New Zealand, Hong Kong, Malaya, Mauritius and East and West Africa emphasised the importance to them of obtaining reports from French possessions, while Bermuda and Hong Kong required reports from the United States and the Philippines respectively. The question of the reports from French possessions was taken up with France but it was not possible to take action regarding the reports from the United States or the Philippines.

As regards reports required by one British Commonwealth Meteorological Service from another, it was suggested to the Dominions and Colonial Offices in May and July 1939 respectively, that the Directors of the meteorological services concerned, should make such mutual arrangements as they considered desirable. A number of the Colonial Services replied that they would require reinforcements of personnel if they had to meet the requirements of the services on a 24-hour basis.[1]

The attitude of the Government of Eire in the event of war was a matter of particular importance to the Meteorological Office, as the observing stations in Eire formed a south-western output of the United Kingdom and often gave the first hint of developments moving in from the Atlantic. It was important, therefore, to ensure, if possible, the continued reception in London of the Eire reports and to deny them to the enemy. Although liaison with the Meteorological Office in Eire was very close on technical matters, political considerations precluded an approach to the Government of Eire at the same time as to the other Dominions on the subject of war organisation.

The proposed withdrawal of the Meteorological Office staff from Foynes during the crisis of September 1938 brought the matter to a head, and in November 1938 the Government of Eire was approached regarding the co-operation of the meteorological services, the exchange of reports and the use of the British meteorological cypher for any of their wireless transmissions which might continue in the event of war. The Eire Meteorological Service was largely dependent on British reports and, at that time, on British staff, to enable it to function and to provide the necessary information for the Transatlantic air service, and, in March 1939, the Government of Eire agreed in principle to the British proposals. The various technical and other reasons underlying the proposals were explained in April 1939 at a meeting between D.M.O. and representatives of the Eire Government, and the Eire representatives promised a fuller official reply. This was not forthcoming, but in August 1939 the Eire Government agreed to continue the existing arrangements for supplying reports from their stations to the Meteorological Office on the understanding that reports and forecasts would continue to be supplied by the Meteorological Office to the Eire Meteorological Service.

[1] A.M. File S.42779.

Arrangements were being made for a representative of the Meteorological Office to visit Dublin when it was learned that the Secretary of the Eire Department of Industry and Commerce (the Department responsible for the Eire Meteorological Service) was in London, and a meeting was held on 1 September 1939 to work out the arrangements in more detail.[1] It was agreed that :—

(*a*) No cypher would be necessary for the transmission of the Eire reports to London by land-line.

(*b*) If the transatlantic air service were continued, it would be necessary to maintain the exchange of reports by wireless between Foynes and Botwood, Newfoundland. It was agreed to use the British meteorological cypher for this purpose, the cypher being in the charge of the senior member of the Meteorological Office staff at Foynes.

(*c*) If the proposed meteorological reconnaissance flight by Harrow aircraft from Ryanna were started, the observations would be sent to London.

(*d*) Efforts should be made to instal a meteorological teleprinter link between Foynes and Southampton via Dublin and London.

(*e*) No more Meteorological Office staff would be withdrawn from Foynes if it could be avoided.

(*f*) The two meteorological services would communicate directly on purely technical questions.

The meteorological cypher was dispatched at once to Foynes and the agreed arrangements came into force on 3 September.

Arrangements with the Foreign Office

The Foreign Office had agreed in principle, in the spring of 1938, to a suggestion that H.M. Representatives in neutral countries should try to obtain, and dispatch to the Meteorological Office, the official meteorological reports of those countries, in the event of the reports no longer being broadcast. As it would require some time to ascertain the requirements of the other meteorological services of the British Commonwealth, it was decided to complete the arrangements for obtaining the reports required by the main Meteorological Office centres.

It was considered impracticable to ask the British representatives to transmit the full series of reports which were broadcast in peace-time, so lists were compiled of the minimum number of reports from each country in Europe, North Africa and the Middle East required by the Meteorological offices in London, Gibraltar, Malta and Heliopolis. The final consolidated list included a total of thirty-two countries. The actual stations in each country from which reports were required were specified in order to ensure a good distribution of reports. It was intended that the reports for the four main hours of observation should be sent, including if possible the 0100 G.M.T. observations.

The consolidated list was dispatched to the Foreign Office in August 1938 and issued by the Department with appropriate instructions about three weeks later.[2] Copies of the British meteorological cypher were also issued to each of the Embassies, Legations or Consulates concerned, in case it should prove

[1] A.M. File S.54956.

[2] A.M. File S.42779.

necessary to cable allied reports through a neutral country, or to cable neutral reports which were being withheld from the enemy through another neutral country. In the summer of 1939, the instructions regarding meteorological reports were incorporated in the general instructions issued to H.M. Representatives abroad regarding action to be taken in the event of war.

'Muria' Reports

Although arrangements had been made with the Foreign Office to try to obtain the official meteorological reports of neutral countries in the event of wireless broadcasts ceasing, it appeared quite likely that the authorities of the country concerned would refuse to issue the reports to the British Representative, as it might compromise their neutrality. In order to avoid a complete blank on the weather chart, it was suggested that, in this event, the British Representatives themselves should make observations and report them to London. Although the reports would not be as full or as accurate as those made by a trained observer, it was thought that if barometers and thermometers were provided, and the elements which the representatives were asked to observe were limited to those which could be measured or estimated with a fair degree of accuracy, without much training, the resulting reports would be of definite value, and would compensate to some extent for the lack of fuller reports from the country in question.

The suggestion was submitted to the Foreign Office in August 1939. Belgium, Holland, Norway, Sweden, Denmark, Faroes and Iceland were mentioned as the countries from which even partial information would be of the greatest value, and Brussels, Liege, the Hague, Groningen, Oslo, Bergen, Tromso, Stockholm, Gothenberg, Thorshavn and Reykjavik were suggested as the most suitable posts from which to obtain reports. It was suggested to the Foreign Office that barometers and therometers should be issued at once to the British Representatives in these places, and that a technical officer from the Meteorological Office should visit the Missions and Consulates to instruct the potential observers. The Foreign Office agreed to the Air Ministry proposals on 25 August, and arrangements were made to put the proposals into effect at once. It was decided that the observers should be asked to report in code present and past weather, visibility, direction and force of the wind, total amount of cloud, atmospheric pressure, dry and wet bulb temperature and the characteristic and amount of the barometric tendency.[1]

In order to avoid drawing attention to the nature of the reports, it was agreed with the General Post Office that the address 'MURIA LONDON' should be used, and that the postal authorities would regard it as synonymous with 'WEATHER LONDON' the normal telegraphic address of the Meteorological Office. It was arranged that as from about 29 August, a technical officer should visit the Missions and Consulates in Belgium, Holland, Denmark, Sweden and Norway in turn, taking with him the necessary barometers and thermometers and detailed instructions. As it appeared that the Foreign Office representatives in Holland were not conveniently situated to obtain reports from the headquarters of the Dutch Meteorological service at De Bilt, and as they had no representatives at Groningen, arrangements were made to attach a Meteorological Office clerk to an unsalaried Vice-Consular post at

[1] A.M. File S.54924.

Utrecht to obtain the reports from De Bilt, or alternatively to go on to Groningen for reporting duties there. The technical officer and the clerk left for Brussels and the Hague respectively on 30 August 1939.

Arrangements with the French Meteorological Service

In April 1936, the D.M.O. pointed out the desirability of examining with the Franch Meteorological Service the arrangements required to ensure the fullest co-operation between the two services and the continued exchange of information in the event of war, as many of these arrangements could not be rapidly improvised. The Cabinet authorised the Air Staff, in the same month, to 'concert the necessary arrangements with the French.' It was decided to conduct negotiations in the first instance through the Air Attaché in Paris, and the various matters which the Meteorological Office wished to raise were set out in a memorandum which was forwarded to him in May 1936 for the comments of the French authorities. The main suggestions of the memorandum were :—[1]

(*a*) France should regard herself as responsible for collecting the reports from the countries from which she collected reports in peace-time.

(*b*) The United Kingdom should be responsible for collecting reports from Iceland, the Azores and Scandinavia.

(*c*) A teleprinter link should be established between the meteorological offices in Paris and London to facilitate the exchange of reports and to avoid the use of wireless and cypher.

(*d*) Each of the two countries should be responsible for supplying to the other and to the Expeditionary Force the reports they were responsible for collecting.

(*e*) A French meteorological liaison officer should be appointed to London and a British liaison officer to Paris.

The memorandum also enquired whether France had any arrangements made or in prospect for obtaining reports from Czechoslovakia, Poland and the Baltic states, and whether they had any methods under development for measuring upper winds in or above clouds.

The French reply, of July 1936, stressed the fundamental importance of a meteorological teleprinter connection between London and Paris in any arrangements for the co-operation of the two services in the event of war, and urged strongly that the teleprinter should be installed in peace-time, ostensibly for meteorological exchanges in connection with civil aviation. It pointed out that no suspicion of preparations for war need be aroused by this move, as teleprinter links for civil aviation purposes already existed between Brussels and Cologne, Paris and Brussels, Paris and Frankfurt on Maine, etc. The note agreed to the division of responsibility for collecting and distributing data and to the exchange of liaison officers. As regards the collection of reports from Czechoslovakia, Poland and the Baltic states, it was stated that no arrangements had been made. Details were given of French developments in measuring upper winds by direction finding on radio sondes, and also regarding experiments which were being made on direction finding on atmospherics. Finally, the note requested information on the arrangements being made to obtain reports from ships in the Atlantic, and from America and Greenland in the event of war, as reports from these areas would be of great importance to the forecasting services of the Allies.

[1] A.M. File S.38063.

The proposal to install a meteorological teleprinter link between London and Paris in peace-time was strongly supported by D.M.O. and D. of S. Estimates of the cost were obtained from the G.P.O., and the French authorities confirmed that they were prepared to meet the cost of the installation in Paris and half the cost of the cross-Channel cable. Expenditure of the British share would amount to approximately £2,600 per annum. Treasury approval was received in June 1937 and the teleprinter link was installed and operating by September 1937.

An interim reply to the French note, stating that the outstanding points were under consideration and informing the French of the proposed immediate establishment of an additional Meteorological Flight in Northern Ireland, was dispatched in December 1936. In February 1937, D.M.O. wrote to the Controller of the Canadian Meteorological Service asking whether arrangements could be made to transmit reports from Canada, the United States and Greenland, and ships' reports from the Western Atlantic, to the United Kingdom by cable or from the new W/T station in Newfoundland in the event of the normal broadcasts from the United States being discontinued. He also drew attention to the difficult problem of ensuring that the Canadian reports did not reach the enemy through the United States in the event of war. The reply of March 1937, from the Controller of the Canadian Meteorological Service, was reassuring on both points.

A suggestion was received from the French authorities in January 1938 that lists of the station reports to be exchanged should be prepared and trials conducted in peace-time. Further information was also requested on the subject of reports from Central and Eastern Europe, America and ships in the Atlantic. The British reply of March 1938 enclosed detailed lists of station reports which should be sent from London to Paris and vice versa, but pointed out that a peace-time trial would serve little useful purpose as the staff at each terminal were fully conversant with the working of the link, and it would not be possible to produce the uncertain war-time conditions in which the reports would be collected. Apart from a statement that the matter was still being considered and was being taken up with the British Foreign Office, no further information was given concerning the collection of reports from Central and Eastern Europe, etc.

A further communication from the French authorities in June 1938 related specifically to arrangements which were being made between France and Czechoslovakia for a mutual exchange of reports in the event of war, and enquired whether the British authorities would be willing to authorise France to include British data in the exchange, on the understanding that Britain would receive reports from Czechoslovakia and that the British reports would be suitably safeguarded by Czechoslovakia. The Air Ministry reply of July 1938 stated that :—

(*a*) If this country were to remain neutral we should continue to broadcast our meteorological observations.

(*b*) If we were in a war as an ally of France, we should then discontinue broadcast information and provide our allies with all information available. Such information would be given to France by the teleprinter circuit already installed between the meteorological offices in London and Paris. Information would be passed to any other allies by the methods most suitable for withholding it from the enemy.

As the international crisis of September 1938 approached, the Director of the French Meteorological Office decided to send two senior members of his staff to London to clarify and complete the various matters which were still outstanding. The main points discussed with the French representatives on 9 September 1938 were :—

(*a*) France had made no final arrangements for obtaining reports from Belgium in the event of the latter remaining neutral and discontinuing the wireless broadcasts of her reports. It was suggested that efforts might be made to obtain the reports through the French Embassy.

(*b*) France had made trial exchanges of meteorological data with Prague by wireless in secret code, but had made no arrangements with any of the other Central or Eastern European countries. The British policy regarding the exchange of reports with allies other than France was reiterated.

(*c*) The naval authorities in both countries had decided that reports from ships must cease in the event of war, but the French proposed to keep their meteorological observing ship, the *Carimare*, in operation. It was agreed that the Meteorological Office would make arrangements for the *Carimare* to use Newfoundland as a base, and for her reports which would be transmitted on low power, to be received in Newfoundland and cabled to London.

(*d*) The French representatives were informed that as much as was possible had been done to ensure that the reports from Canada and the United States were available.

The teleprinter link between London and Paris was converted in November 1938 to duplex working (*i.e.* messages could be sent simultaneously from London and Paris) although for some time afterwards only one machine was available in Paris and full duplex working could not be used. It was agreed to conduct a series of trial transmissions, sending by teleprinter the collective messages which were normally broadcast from Paris by wireless. The trials were carried out in December 1938 and January 1939 and proved to be generally satisfactory.

The French Air Ministry raised in July 1939 the question of an exchange of meteorological information with Poland in the event of war. The exchange was agreed in principle by the Air Staff and it was decided to leave the details to be discussed at a Franco-British Signals and Meteorological Conference which was then being arranged. The conference opened in Paris on 10 August 1939, the main meteorological items on the agenda being :—

(*a*) The arrangements for the exchange between England and France of meteorological information for civil and military flying between England and France and for general forecasting purposes.

(*b*) The provision of meteorological information for long distance through routes, *i.e.*

(i) Western and flying boat routes across France to the Mediterranean ;

(ii) Northern route via Scotland to Scandinavia.

(*c*) The exchange of meteorological information between French Colonies and British Dominions and Colonies.

(*d*) The provision of meteorological information for British overseas air routes.

(*e*) The transmission of British and French meteorological reports to Poland and vice versa.

(*f*) The provision of meteorological reports from neutral countries.

In fact, the discussions covered a considerably wider field than that laid down in the agenda. Besides arranging the exchanges necessary for aviation purposes, and confirming the arrangements already made for the exchange of data and the supply of information to the meteorological section with the Expeditionary Force, the conference agreed on a number of security measures including the use of land-lines whenever practicable and of regional cyphers which were to be prepared in Britain. The use of a common Franco-British cypher for fleet synoptic messages was also suggested. The importance of reports from the Atlantic was stressed and another approach to the French and British naval authorities suggested regarding the possibility of some ships at least continuing to send reports. Arrangements to obtain reports from reconnaissance aircraft and a more dense network of aircraft ascents and radio sonde stations in the western districts of France and the United Kingdom were also recommended. It was agreed that the arrangements made through the British Foreign Office should be used to obtain reports from Poland and other countries, and that meteorological information to Poland should be supplied by the British Embassy in Warsaw, which would intercept and decypher the fleet synoptic messages, and communicate the decyphered reports to the Polish Meteorological Office. In case the British representatives were unable to obtain the official reports of a neutral country, it was suggested that instructions should be issued to them so that they could make observations themselves and transmit them to London.

There was little time left to put the recommendations of the conference into effect, but considerable progress was made before the outbreak of war.[1] The issue of the British Confidential Meteorological Code to the French was authorised to enable the British Fleet Synoptics to be used, and arrangements were made to issue meteorological instruments to a number of British Embassies, Legations and Consulates. The Admiralty, however, were unable to agree to ships continuing to report, but it was pointed out that in exceptional circumstances the Commanders-in-Chief could, at their discretion, instruct any ship to report if it was considered that the report was sufficiently important to justify it.[2] D.D.Ops. (N.C.) was approached regarding reports from reconnaissance aircraft but war had broken out before arrangements could be put into effect.

Reports from Ships

Reports from the Atlantic are of paramount importance in forecasting the weather in Western Europe, as many of the weather systems affecting the area move in from the west. In peace-time an organisation existed for obtaining reports by wireless from selected ships of the mercantile marine, in order to fill in the blank in the weather chart which would otherwise exist over the ocean. It was clear that these reports would be even more important in war when the forecaster would be confronted with other blanks on his chart over enemy territory.

[1] A.M. File S.38136. [2] A.M. File S.38063.

Unfortunately, other important considerations were involved, and the Admiralty decided that strict W/T silence must be enforced to avoid disclosing the positions of convoys or individual ships. Only one concession was made, viz. that if the reliability of a forecast for an important service operation was likely to be considerably reduced if no observations were available from sea areas, the Naval Commander-in-Chief could, at his discretion, instruct a certain ship to transmit a report. This concession had little practical importance, as an isolated report had small value for forecasting purposes as compared with a regular series of reports. So much importance was placed on ships' reports that the Admiralty were asked in May 1938, and again after the Franco-British Meteorological Conference in August 1939, to reconsider their policy. On both occasions, however, the Admiralty were unable to make any further concessions and their previous policy remained in force at the outbreak of war.

Technical Problems

Single Observer Forecasting

Single Observer forecasting (*i.e.*, forecasting on the assumption that all communications have failed and that only the eye and instrument observations made by the forecaster himself are available) was a subject to which much thought was given before the war. It was a problem of particular interest to the Navy, and as early as 1928 the Admiralty seconded an officer to the Meteorological Office to study the question. In March 1937 the Air Defence Research Sub-Committee of the Committee of Imperial Defence asked D.M.O. to prepare for their consideration a report on single observer forecasting with particular reference to means for training personnel in its use.[1]

The shortage of staff in the Meteorological Office prevented further investigation of the problem but it was included among the subjects for study by the section which at that time it was proposed to form to deal with the war organisation of meteorology. D.M.O. and Admiralty representatives decided at a meeting in June 1937 to prepare a resolution for the Air Defence Research Committee emphasising the importance of the question and the desirability of appointing naval officers to study the problem on the various naval stations after a course of instruction. The meeting recognised that much had been done to develop single observer forecasting, especially on the theoretical side, but considered that more officers, especially naval officers, should be trained and exercised in this method, as experience was of major importance. The frequent use of aircraft in this connection both for height and distance would hasten its further development. The committee recommended that naval officers, out of the zone for promotion and preferably observers, would be selected for training in Single Observer forecasting and appointed to ships and shore foreign stations to devote their whole time to the study and practice of this method. As the curtailment of synoptic information was not likely to be so complete on land as at sea, Single Observer Forecasting had not the same importance for the land forces, but the Sub-Committee considered that the method should be studied by the staff of the Meteorological Office, and form a definite part of the training of the War Meteorological Section. The Sub-Committee also recommended that the Air Staff should consider the possibility of training a number of regular Air Force officers in single observer forecasting in order to study the possibilities of the method on land stations.

[1] A.M. File S.41509.

As the permanent staff of the Meteorological Office could not be taken off their normal duties for training in single observer forecasting, it was decided to issue D.M.O.s report on the subject to all Meteorological Office forecasting centres so that the staff could study the problem. The suggestion that regular R.A.F. officers should be trained in the method does not seem to have been pursued. In January 1939, the Admiralty decided to appoint a Naval officer qualified in meteorology to each foreign station for a period of five years to devote his whole time to the study and practice of single observer forecasting, and the Meteorological Office stations at Malta, Gibraltar and Heliopolis were instructed to co-operate with these officers.[1]

Forecasting with Incomplete Maps and the Making of Weather Observations by Aircrews

The accuracy which route forecasts for R.A.F. Bomber operations might be expected to attain under war conditions, when no information would be available from enemy and possibly neutral territory, was a subject which received much attention before the war. In February 1937, a memorandum was prepared showing the vector errors in wind forecasts which might be expected for various heights, time intervals and distances from the area of available observations. Statistics were given for flights from this country towards Germany and from Germany towards this country, looking at the problem from the German forecasters' point of view in the latter instance. In each case, appropriate assumptions were made regarding the countries from which the reports would be, or would not be, available to the forecasters. In 1937–38 a similar investigation of cloud forecasting was undertaken. The results of the investigations made it very clear that even limited observations from enemy territory would be of the greatest value to forecasters, and the R.A.F. Meteorological Policy Committee recommended in April 1938 that bomber crews should make weather observations over enemy territory, and that an organisation should be developed to train the crews, standardise the type of report and ensure that the reports were made available to the forecasting service without delay.

After discussions between the Air Ministry and the Commands concerned, a standard form for recording reports was evolved and issued to the Commands in January 1939.[2] The new form for the crews' reports was printed on the back of the form on which route forecasts were normally issued. Provision was made for reporting time of observation, the position of the aircraft, sensitive altimeter readings (height and subscale), temperature, cloud type above and below the aircraft and remarks. The Air Ministry informed Commands in January 1939 of the new procedure and suggested that weather reports should be called for on all operational and navigational training flights in Bomber and Coastal Commands and that the School of Air Navigation and School of General Reconnaissance should also practise pupils during their more advanced instructional flights. In March 1939 detailed instructions were issued to the meteorological offices concerned regarding instruction and guidance to aircrews and the collection, coding and transmission of the reports.

The functioning of the scheme was reviewed, when a few months' experience had been gained, by the R.A.F. Meteorological Policy Committee in January 1939. It was agreed that, on the whole the reports returned by the

[1] A.M. File S.50986.

[2] A.M. File S.45354.

aircrews were satisfactory, and although they contributed little additional information in peace-time, they would be of considerable value in war. It was decided that the arrangements for obtaining these pilots' observations, or 'plobs' should be continued, and the procedure remained in force until the outbreak of war.

The possibility of using meteorographs (self recording meteorological instruments) on bomber aircraft was considered during the pre-war period, but was never put into practice for the following reasons: the lack of a suitable instrument more robust than existing instruments; the necessity for the evaluation of the records by an expert before the information could be used and distributed, a process which would involve considerable delay, particularly if the aircraft landed at a satellite airfield.

PART II

SUPPLY OF METEOROLOGICAL DATA IN THE BRITISH ISLES AND TO EXPEDITIONARY FORCES IN NORTH-WEST EUROPE

CHAPTER 3

THE CENTRAL FORECASTING OFFICE

Before the war, the forecasting work at the Central Forecasting Office consisted of two main parts: a senior forecaster analysed the chart, wrote out the forecasts for the Press and B.B.C. and issued the forecasts and gale warnings for shipping; and an aviation forecaster was responsible for a meteorological broadcast for aviation and other aviation forecasts, including warnings for airfields, *i.e.*, of gales, squalls and thunderstorms. During the day, the work of the aviation forecaster was directed by the senior forecaster, but for about ten hours at night no senior forecaster was on duty and the aviation forecaster was wholly responsible for the forecasting, including gale warnings for shipping, the distribution to outstations of analyses of the synoptic situation commenced shortly before the outbreak of war.

The Central Forecasting Office moved to Birmingham temporarily in August 1939, but in February 1940 it moved to its permanent wartime location at Dunstable. The code name for the evacuation headquarters of the combined Central Forecasting Office and Meteorological Communications Centre was 'ETA,' a word which came to be used generally as an abbreviation for the Central Forecasting Office and Meteorological Communications Centre as a whole.

Forecasts to the public ceased on the outbreak of war, and the main function of the Central Forecasting Office was to give technical advice to outstations on the broad weather developments to be expected, thus ensuring a general co-ordination of the forecasts issued by the Meteorological Office forecasting units in the United Kingdom and N.W. Europe. As the Central Forecasting Office was in the same building as the Communications Centre, it had access to the latest available information, and, in cases of doubt or disagreement, was regarded as the ultimate authority. In addition to the routine issue of technical guidance, the Central Forecasting Office issued forecasts and warnings of general application, *e.g.*, fog and gale warnings. It also issued many special forecasts to recipients who were not covered by the meteorological organisation provided for the Royal Air Force and the Army.

General Forecasting Work

Technical Bulletins for Outstations

The routine method of providing guidance to the outstations was by bulletins broadcast by teleprinter and wireless, which contained forecasts and analyses of surface and upper air conditions.

Soon after the outbreak of war, the distribution of frontal analyses to outstations was extended to include all four main charts.[1] From 1940, the pressure distribution was added (*i.e.* the positions of centres of high and low pressure,

[1] Meteorological synoptic observations are made at standard times. In Europe 0100, 0700, 1300, 1800 were referred to as the 'main' hours, and 0400, 1000, 1600 and 2200 as the intermediate hours. The corresponding charts on which the observations are plotted are referred to as 'main' charts, etc.

cols and points on selected isobars were shown) and the message was called a 'baratic.' The analyses were supplemented by a General Weather Outlook. From early 1942, the forecasts included a 'prebaratic' (forecast chart of pressure distribution and fronts) three times daily, later extended to all four bulletins. The main wartime advance in forecasting technique was the regular construction and distribution of the pre-baratic charts which, ever since their introduction, have been the foundation of the whole forecast system. They enabled outstations to obtain a much clearer picture of how ETA viewed the latest developments, and greatly increased the outstations' use of the ETA bulletins; they also helped forecasts made directly by ETA. Forecast charts lead to greater precision in the forecasts, which, although not always justified, is generally a gain, especially for short-period forecasting. For forecasts which begin only some 12 hours after the current chart, the chief advantage of the pre-baratic is that it tends to prevent excessive pre-occupation with present conditions. The forecast charts have also made it possible to obtain a numerical check on forecasts of pressure (including the position of centres) and the position of fronts.

The timetable of routine weather forecasts for aviation at the outbreak of war had been designed to meet normal peace-time requirements of the R.A.F. and private flying, and the times of issue and periods covered by the forecasts varied accordingly. All the forecasts contained a brief statement of the meteorological situation and the location of fronts at the time of issue, followed by a series of forecasts covering Great Britain and N. Ireland of probably surface wind, upper winds at 2,000 to 3,000 feet and 6,000 feet, weather, clouds and visibility. This procedure continued until July 1941, when detailed forecasts were issued at 3-hourly intervals and the period of the forecasts was standardised as 12 hours. For example, a forecast issued at 2.40 a.m. based on the 1 a.m. chart referred to the period 3 a.m. to 3 p.m. The contents of the forecasts were substantially as before. A forecast for the following day in general terms was issued at 3.40 p.m. From February 1942, the aviation forecasts formed part of the forecast bulletins, thus making the statement of pressure distribution and frontal analysis unnecessary. From July 1942, the forecasts began with a statement of cloud types, thicknesses, etc., and were supplemented by upper wind forecasts up to 30,000 feet. A forecast for the North Sea, N.W. Germany, the Low Countries and Northern France was broadcast in the form of an aviation forecast twice daily.

Warnings

In addition to the routine bulletins, warnings of certain weather phenomena were broadcast when the need arose :—

Fog Warnings : Broadcast by teleprinter began in the autumn of 1940 as an anti-invasion measure, and were at first issued to Service recipients over a substantial area of the country and indicated whether the fog was likely to persist all day. These warnings proved so useful that they were continued as a routine after the danger of invasion was past.

Snow Warnings : were prepared, from November 1941, by the Central Forecasting Office and broadcast on the meteorological teleprinter network to supplement the information given in the routine forecasts: they were passed on by outstations to the local R.A.F. authorities. In the winter of 1942, thaw and frost warnings were added; at the request of the Ministry of War Transport these were also relayed by outstations in code to many road engineers and public authorities.

Gale, Squall and Thunderstorm Warnings : for the British Isles continued to be prepared by the Central Forecasting Office and broadcast by teleprinter during the war, and were distributed either by outstations or direct from ETA. The terminology to be used in the warnings and the procedure for their distribution were laid down with more precision in the spring of 1943.[1] At the same time, the British Isles, British Coastal areas and North Atlantic and North Sea were divided into areas for use with these warnings and for other forecast purposes whenever areas required definite specification.

Telephone Conferences

Consultations at about 9 a.m. with the Senior (later Chief) Meteorological Officer at Bomber Command, on the prospects for the following night began in 1940. From January 1942, ETA was linked to the telephone conferences between the meteorological offices at Bomber Command and the Bomber Groups which took place at least once daily; in difficult situations there was a special conference shortly before take-off. ETA was always represented either by the Chief Forecaster or the senior forecaster on duty. In addition to the operational aspect, these conferences provided a useful exchange of views on the general meteorological situation. The function of ETA was to give technical advice and its opinion was often asked on very definite questions related to the exact cloud height and visibility, or the percentage of airfields in the whole area of Bomber Command which could be expected to remain open (with cloud height and visibility above a specified minimum) up to the time of the bombers' return. The 'Sferic' reports were of very great importance in the summer and valuable new information sometimes become available during the conference.

Telephone enquiries from, and conferences with, other Command and Group Meteorological Offices occasionally took place when the situation was difficult or when there was some especially difficult flying operation. A close liaison was maintained with the Naval Meteorological Service, which was responsible for issuing meteorological warnings to shipping, in connection with the issue of gale warnings. Shortly before the Rhine crossings, telephone conferences were held with the meteorologists in England forecasting for the airborne landings.

Observations and Charts

The war led to an immense growth in the number of observations in the British Isles, the gain being especially noticeable at night. The much fuller information at the intermediate hours was of great value for short-period forecasting, and the same was often true of the hourly observations although these were only used as required. The main value of the hourly observations was for short-period aviation forecasting at the out-stations.

For forecasting for more than a few hours ahead, the gain from the increased information in the British Isles was outweighed for some years by the lack of information from the Atlantic. This was mitigated in 1941 and 1942 by the two special ships sent out by the Admiralty, but these were sunk by enemy

[1] A.M.O. A.383/43.

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action. For some time after this, there was little Atlantic information, as reconnaissance flights were still in the experimental stage, although extremely valuable observations were received from the Captains of British and American aircraft flying regularly between air bases on both sides of the Atlantic. ' In flight ' reports were decyphered at Prestwick and relayed to ETA by teleprinter whilst ' post-flight ' reports were put into the appropriate coded form by the terminal air bases and the message again reached ETA via Prestwick. A considerable number of the reports were made at heights between 10,000 and 20,000 feet. In the absence of any other information, they were of great use in fixing the position and following the movement of fronts. Subsequently, the position was greatly improved by the increased frequency and range of meteorological reconnaissance flights. The low-level observations were very valuable in locating fronts, and the ascents provided entirely new information. In 1944/45 observations from British naval vessels in fixed positions became available to supplement the observations made by the American fixed ships network (U.S. Weather Patrol Ships) which had been developed during the two preceding years. The ' Sferic ' reports obtained by direction finding on atmospherics, proved of great value in locating thunderstorms, especially on the Continent ; they often supplied the first information of the development of thundery disturbances and also helped in locating fronts on the Atlantic.

Charts on the scale 1 in 7½ million were introduced in 1940 and became the main working charts in 1942. The 1 in 10 million charts which had been the fundamental working charts for some decades were then dropped as the scale was too small to allow the modern ' station model ' to be plotted fully at enough stations. Atlantic charts on the scale 1 in 15 million replaced the old 1 in 20 million Atlantic charts at the same time. A frontal analysis over the whole Atlantic area was included in the Daily Weather Reports from February 1942. Previously, the analysis had been carried out as far as the observations available permitted, but was not issued.

Staff

The extension of the senior forecasters' roster to cover the whole 24 hours was a wartime necessity. At first, only three forecasters were available ; one slept at the office and was only roused when warnings had to be sent out or there was some unforeseen development in the synoptic situation. From the spring of 1940 there were four senior forecasters and a 24 hour roster was then maintained. The steady increase in the number of forecasts to be issued made it necessary to relieve the senior forecasters of some of the routine day-time forecasts, especially after the introduction of the pre-baratics. By the autumn of 1942, seven forecasting officers (independent forecasters) were normally engaged on miscellaneous and aviation forecasting, additional to the senior forecasters.

Upper Air Work

The outstanding new feature of war-time meteorology was the immense development of upper air soundings. At the outbreak of war meteorological aircraft ascents were made twice daily at Mildenhall and Aldergrove up to the 400 mb. (approximately 23,000 feet level). Ascents were also made at a number of places on the Continent, especially in Germany. Contour charts of the 500 mb. (approximately 18,000 feet) were drawn regularly in Germany,

but since the only area with adequate data was located east of the British Isles, such charts were of little value to British forecasting. The only upper charts drawn here were for 1 and 2 kilometres (3,280 and 6,560 feet approximately) which were published in the Upper Air Section of the Daily Weather Report but these heights were too low for the charts to be of much use for forecasting in a mainly low-lying area like the British Isles.

The most serious gap in our information was in respect of upper winds in cloudy weather.[1] When the first radio wind sounding was received from Larkhill in October 1939 it was at once realised that it opened a new era in synoptic meteorology. There was a steady increase in 1940 in the information both of upper air temperatures and humidity and of wind, and meteorological reconnaissance flights extended the area of observation into the Atlantic. The establishment by the U.S. Coastguard of meteorological ships with radio-sounding equipment in 1944 enabled fairly reliable upper air charts to be extended right across the Atlantic, thus opening a new era in British synoptic meteorology.

From January 1940, isobaric charts for 2 and 5 kilometres (6,560 and 16,400 feet approximately) were prepared daily and distributed to outstations and also issued in the Upper Air Section of the Daily Weather Report. A year later, they were replaced by height contours of isobaric surfaces, *i.e.* surfaces of equal pressure. Charts for the 750, 500 and 250 mb. (approximately 9,000, 18,000 and 34,000 feet) surfaces were prepared daily for 0400, 1200 and 2000 G.M.T., those for 0400 at 500 and 250 mb. being issued in the Daily Weather Report. The charts showed contours both in heights above sea level and of the thickness between successive isobaric surfaces, in the case of the 750 surface the thickness being taken from the 1,000 mb. surface, which is very closely related to the sea level isobaric chart.

Forecast upper charts (Prontours) were made for a period 12 hours ahead and issued in coded form to outstations. Charts of the height of the tropopause were also drawn and issued ; later these were supplemented by forecast tropopause heights. The height of the tropopause was operationally important as the air in the stratosphere is normally too dry for persistent condensation trails (' contrails ') to form. The ' Mintra ' message, which was also issued referring to contrails, gave the minimum height in the tropopause below which persistent contrails would not normally be found.

The Evolution of the Upper Air Branch

Until about the middle of 1940 the upper air information could be handled by the ordinary forecasting and plotting staff but it subsequently increased to an extent where it became necessary to have a special section to deal with it. At the end of 1942, the section became a new branch, the work of which continually increased until shortly before V.E. day. This was due partly to the increasing number of observations but even more to the increase of routine and operational forecasting requirements.

The main innovation on the upper charts was the introduction of tendencies of contour heights and thicknesses, and tendency of temperature on the isobaric surface. Thermal winds averaged over the layers between the various isobaric surfaces were also plotted in addition to actual winds. The location of

[1] The normal method of measuring upper winds was to release a small hydrogen filled balloon and follow it visually by means of a special theodolite, a method which is naturally useless when the balloon enters cloud or there are very strong winds.

fronts in the upper air was introduced but, as fronts are generally diffuse aloft, the subjective element was large and the number of fronts shown on the upper charts greatly decreased during 1944 despite increased information. Charts extending across the Atlantic and America at 700 and 500 mb. commenced in 1943, and by 1944 the Atlantic network became adequate to ensure a fair degree of accuracy.

Forecasting Upper Winds for Bombing Operations

In addition to the increase of routine upper air forecasting, resulting from the synchronisation between the upper and surface air charts which was made possible by making four instead of three sets of upper air observations daily, there was a great development, of operational forecasting. Before 1943, meteorological officers at the Bomber Groups made their own forecasts of upper wind, but the increased scale of the concerted operations and the development of the Pathfinder technique with immense concentrations of bombers over the target, made it essential to have a single forecast of upper wind in any given area. For some time the operational upper wind forecasts for various routes (normally divided into 'legs') and targets were supplied by ETA; later an upper air section was formed at Bomber Command.

The forecasts were based on the ETA special 'prontours' for the operational area and a constant liaison was needed between the two upper air units. The prontours required for the bombing operations were normally additional to those made for standard pressure and standard times. It was necessary, therefore, to have two rosters, one for operational forecasts and the other for routine analyses and forecasts. Daylight raids by Bomber Command began in 1944, so that operational forecasts were often needed at any time of day or night. The development of the technique of wind-finding by the bombers themselves also involved special duties for upper air forecasters, in continuous liaison with Bomber Command; the original forecasts had to be immediately corrected, when necessary, in the light of the information received.

When the new Branch was formed, provision was made for research and, although the severe operational demands limited this, a substantial number of research papers were prepared by the staff, some of the most important being, perhaps, those on Subsidence and Convection. In addition, forecasts of the Larkhill upper winds were made for checking purposes.

Charts and Diagrams

From 1943, the standard upper air charts were on the same scale as the surface charts. A new tephigram was designed on half the scale of the old one for use with radio-soundings up to or above the 100 mb. level. Later, a larger tephigram was produced on the original scale, suitable for radio-soundings in all parts of the world. All values were recomputed and various improvements effected. Cross-sections were drawn with a horizontal scale of 1 in 7½ million and vertical scale exaggerated 200 times. A length of 2,800 miles could be covered. The Upper Air Section of the Daily Weather Report was expanded at the beginning of 1942, with morning charts for 750 mb. (later 700 mb.), 500 mb. and 250 mb. (later 300 mb.) and the height of the tropopause. A trans-Atlantic 500 mb. map for the evening was included from January 1944, by which time the number of temperature ascents had increased to over 50 daily and there were 16 radio-wind soundings and a large selection of pilot balloon ascents.

Special Forecasts, Summaries and Warnings

In the arrangements for meeting the day to day needs of the R.A.F. and Army, the Central Forecasting Office acted as a general guide and consultant, but it was also called upon to issue a substantial amount of information in addition to the routine bulletins which were broadcast to the outstations. A considerable number of routine forecasts and summaries of past weather were issued to Service and other Government Departments and essential services which were not served by the meteorological organisation provided for the R.A.F. Commands and the Army. They were issued either directly to the recipients, or through the liaison section of the Central Forecasting Office at Meteorological Office Headquarters. From time to time, the Central Forecasting Office was called upon to issue special forecasts or series of forecasts for a number of reasons, such as :—

(*a*) the recipient was not served by the normal organisation ;

(*b*) the forecasts applied to more than one Command ;

(*c*) the forecasts were required to cover a longer period than usual ;

(*d*) the application of special upper air information was required ;

(*e*) the forecasts were of an unusal character.

The main special forecasts issued were as follows :—

'Volcano' (later 'Furnace') Warnings—Enemy use of smoke : started in July 1940 and concerned wind conditions suitable for the use of smoke generated on the Continent as a screen for enemy landings on the south and east coasts.[1] The forecasts, which were discontinued in October 1941, were distributed to the Admiralty, War Office, G.H.Q. Home Forces and H.Q. Coastal Command.

'Forceps' (later 'Simplex') Coastal Gas Warnings : were forecasts of winds on the south and east coasts of the British Isles and began in August 1940 as an anti-invasion measure. They indicated the stretches of coast from North Berwick to Hartland Point on which wind conditions would be suitable or otherwise for the use of gas by invading forces during the hours of darkness.[2] The forecasts were distributed by meteorological teleprinter and Service channels to Army Commands, R.A.F. Commands and Groups, who distributed them to units within 5 miles of the coast in question. They were discontinued in October 1941.

'Windotern' Forecasts : of upper winds and temperatures were issued from August 1940 at 0200, 1000 and 1800 hours B.S.T. daily to the Admiralty in connection with the firing of heavy guns across the Straits of Dover. They gave estimates of the main wind and temperature for each 4,000 feet layer up to 48,000 feet and referred to a time 4 hours ahead of the time of issue.

'Cliquot' Forecasts : were supplied to Bomber Command and B.Ops 1 in connection with a project to set fire to the forests of Germany by means of incendiary weapons. They involved estimates of past weather, including rainfall, and future weather and winds. They were begun in July 1940 and discontinued in October 1941.

Fog Warnings : were issued from September 1940 as an anti-invasion measure, so that fighter aircraft could be moved from threatened airfields

[1] A.M. File S.62678. [2] A.M. Files S.6127 and S.62678.

to those which were likely to remain clear. They proved of such value to outstations that they continued as a routine after the threat of invasion had passed.[1]

'Papyrus' Forecasts: of the drift of no lift balloons at specified heights, and of weather, cloud and icing conditions affecting the balloons, were sent from November 1941 to the balloon Units which distributed propaganda leaflets,[2] and occasionally to those experimenting with no-lift balloons across the British Isles.

Forecasts for flights to Russia: were supplied by the Central Forecasting Office for about a year from July 1941. This work was later taken over by the meteorological office at Prestwick.

'Nebular' Warnings of Snow, Frost and Thaw were distributed in the teleprinter network for general information and for the use of local authorities.

Forecasts for N. African Landings: Both before and after the N. Africa landings special outlooks as far ahead as possible were sent out in wireless by cypher for the benefit of the meteorologists responsible for forecasting in that area. Special upper wind forecasts were made for the flights from England to Africa.

'Fido' Forecasts: of temperature inversions and fog were sent from December 1942 to places where experiments were being made on fog dispersal.[3]

'Snoly' Reports: of snow conditions in European countries from Norway to Italy were issued to Bomber Command and Group H.Q. from November 1943. They included estimates for the various countries of the approximate level above which snow would be lying, the approximate thickness in flat country and on the level among mountains, the distribution of the snow cover, *e.g.* patches, and whether the snow was thawing.

'Naviprop' Forecasts: of the variation of the water vapour content of the air with height, at low levels over the North Sea, were issued from November 1943, as the vertical distribution of water vapour in the lower layers of the atmosphere was known to affect the patch of short wave radio beams, especially the 'Oboe' system of guiding bombers over a target.

'Annoprop' Forecasts: regarding meteorological conditions around the coasts of Britain suitable for the anomalous propagation of short wave radar, began in February 1944, and were distributed to C.s-in-C., Nore and Plymouth; H.Q. VIII Fighter Command U.S.A.A.F. Duty Officer Coastal Artillery Dover; H.Q., A.D.G.B., and other interested authorities.

Bramart Forecasts: For some time after the landing in Northern France, short term forecasts of winds, pressures and temperatures for various levels up to 30,000 feet were broadcast by wireless every four hours to assist the meteorologists with the Expeditionary Force in compiling Artillery Meteor Reports.

Government Departments: Many special forecasts and warnings were issued for Government Departments and essential services.

[1] A.M. File S.65105. [2] A.M. File S.62621. [3] A.M. File S.84807.

CHAPTER 4

BOMBER COMMAND

The meteorological organisation for Bomber Command, as approved before the war, remained virtually unchanged throughout the war, except for the partial upgrading from Type 3 to Type 2 of the meteorological offices at Base Headquarters in 1944–45. By August 1939, meteorological forecasting centres had been provided at the six Bomber Group Headquarters (Nos. 1, 2, 3, 4, 5, 6) and subsidiary meteroological offices at the bomber airfields.[1] A meteorological teleprinter network connected each meteorological office at an airfield to its parent at Group H.Q., and each meteorological office at a Group H.Q. to the Central Forecasting Office. Also, immediately before the war, a forecast centre was provided at Command H.Q. with a teleprinter link to the Central Forecasting Office.

In accordance with the policy of making the meteorological organisation conform to the Command organisation, Type 1 meteorological offices were provided at No. 7 Group (O.T.U.) H.Q. towards the end of 1941 and at No. 8 Group (Pathfinder) H.Q., No. 6 Group (R.C.A.F.) H.Q. and No. 100 Group (S.D.) H.Q. towards the end of 1942. Although it was a Canadian Group, the meteorological staff at No. 6 Group H.Q. and stations were all supplied by the Meteorological Service, who, in turn, provided meteorological staff to replace those who had been sent from the United Kingdom to the R.A.F. Training Schools transferred to Canada. Initially, all the meteorological assistants at No. 6 (R.C.A.F.) Group H.Q. were also provided by the Meteorological Office, but towards the end of the war, some of them were replaced by Canadian airwomen. In the final stages of the war, the Command contained seven operational Groups, a Heavy Conversion Group and two Training Groups. At Command H.Q. and at each Group H.Q., except No. 7 (Heavy Conversion) Group, a Type 1 meteorological office was maintained.

The Senior (later Chief) Meteorological Officer at Command H.Q. was responsible for advising the Commander-in-Chief, and acted as liaison officer between the Air Staff of the Command and Meteorological Office Headquarters. The Senior Meteorological Officer at a Group H.Q. was responsible for all meteorological work in his Group and personally advised his A.O.C. He was assisted at Group H.Q. by a team of independent forecasters large enough to provide a continuous forecast service. The meteorological officers at Groups and Command worked as a team to provide meteorological advice for major bombing attacks, which were co-ordinated from Command H.Q., but some attacks on special targets and minelaying operations were the responsibility of Groups individually, and the duty of advising Air Staff for these operations was exclusively that of the officers at Group H.Q. In general, the meteorological staff in Training Groups were responsible for advising on weather prospects for individual training flights and leaflet dropping sorties, but when,

[1] A.M. File S.83658.

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towards the end of the war, Heavy Conversion and Training Groups played a part in major operations by making diversionary sweeps to deceive the enemy as to the direction of the main attack, the meteorological staff concerned were brought into the co-ordinated meteorological arrangements.

The policy of providing each R.A.F. station in the Command with a Type 3 meteorological office, manned by 'dependent' forecasters and the necessary complement of airmen meteorologists for maintaining routine weather observations and plotting synoptic charts, was varied in January 1944, when it was agreed to appoint an independent forecaster to the H.Q. of a Base (*i.e.* a 'clutch' of three stations one of which was the Base H.Q.). The independent forecaster acted generally under the S. Met. O. at the parent Group H.Q., but was responsible for the supply of meteorological advice for non-operational flights by units within the Base. There were normally two dependent forecasters at each station in the Base in addition to the independent forecaster at Base H.Q. It was decided at the end of 1944 that a W.A.A.F. Meteorological Officer should be employed at each of the Command O.T.U.s and H.C.U.s.

It was the duty of the meteorological staff at Command to advise the Commander-in-Chief, to co-ordinate the advice given throughout the Command for operations which involved more than one Group, to advise Central Flying Control, to determine upper winds for all purposes for which they were required in the Command and to decide when and by what route sorties by 'Pampa' weather reconnaissance aircraft were required. The duties of the meteorological staff at a Group were to advise the A.O.C., to give guidance to forecasters at the stations, to administer the work at the Type 3 meteorological offices and to advise Control at Group H.Q. when diversion of aircraft was necessary. The main duties of the meteorological staff at a station were to pass to the Station Commander the advice obtained from Group H.Q. regarding the prospects for operations or other sorties, to brief the crews with forecasts received from Group H.Q., to prepare the forms which contained these forecasts and issue them to the crews concerned, to obtain weather information from the crews on return from operations or training flights and to maintain and transmit observations to Group H.Q. hourly, or more often if necessary. Station forecasters always worked under the guidance of the forecaster at Group H.Q. from whom he received forecasts by teleprinter or telephone and with whom he discussed the synoptic situation whenever necessary.

The usual practice at briefing was for the station meteorological officer to display and describe the latest synoptic charts, and a pictorial cross-section of the weather conditions expected on the routes usually with the aid of an epidiascope, and to answer queries. In addition, aircrew members, particularly navigation officers, visited the meteorological office immediately before take-off for a further discussion with the forecaster, especially if Group H.Q. had amended the briefing forecast. The forecasters at the stations interrogated crews on return from an operation and obtained in this way a reasonably correct and comprehensive picture of the weather experienced. The information obtained was summarised by the forecaster and forwarded to Group H.Q. where a composite message was prepared, based on the summaries from all stations. These messages were in turn passed by teleprinter to the Central Forecasting Office for broadcasting so that meteorological information from over enemy territory could be made available to all forecasting units in the British Isles.

Following a partial reorganisation of the Meteorological Office, a section of the H.Q. Branch dealing with the requirements of Bomber Command was opened at Command H.Q. in September 1944. The Head of the Branch, who was responsible for supervising and co-ordinating the meteorological services in the Command, carried such powers as were delegated to him by the Director of the Meteorological Office to enable a substantial number of the meteorological questions arising within the Command to be settled without reference to Meteorological Office H.Q. The Chief Meteorological Officer at Command H.Q. was thus able to maintain personal contact with the Head of the Branch and, as meteorological adviser to the Commander-in-Chief, kept the Head of the Branch informed of the meteorological requirements of the Commander-in-Chief, particularly in regard to matters related to organisation.

Co-ordination of Meteorological Work

Early in the war, when Groups operated independently, decisions on the suitablity of weather conditions for particular operations were made generally by Group Commanders acting on the advice of their respective Senior Meteorological Officers. As operational planning became complicated by the increase in the numbers of aircraft and the intricacies of the methods of attack, these decisions were made increasingly by Air Staff at Command H.Q. consulting with Group Commanders, although decisions relating to details of take-off and climb remained primarily a Group responsibility throughout the war. Thus the stage was reached where an operation was planned partly on the meteorological advice given at Command and partly on advice given at Groups, the Meteorological Officers at Command and Groups acting independently. In order to co-ordinate the meteorological work and obtain the best results, meteorological conferences by secret telephone with the Meteorological Officers at Command and all Operational Group H.Q., linked together simultaneously, began in December 1940 and continued until the end of the war. Early in 1942, the Bomber O.T.U. Groups and the Central Forecasting Office were included in these conferences which were held daily in the afternoon in summer and at midday and in the afternoon in winter. Additional conferences were called if necessary.

In order to increase their value, the form of these conferences was changed in the light of experience until the following final form was reached. The Command Meteorological Officer first described the meteorological situation as he saw it, told of the advice he had given to the C.-in-C. and named the operations which had been laid on as the result of that advice. The Chairman of the day, whose place was taken in turn by the Senior Meteorological Officer in person at Command and at each of the Operational Groups, then took over. He took the main responsibility for weather advice in the Command for 24 hours from about 0900, and ensured that all the latest possible information was plotted on his weather charts accurately, and personally kept very careful watch on all weather developments. This did not absolve the Groups from their normal careful routine. It was also the chairman's duty to acquaint himself with all the operations scheduled to take place throughout the Command during his 24 hours of duty, and to assess the weather according to the areas and ranges of such operations and, therefore to the periods of time covered. Having heard Command's views, the chairman at the first conference of the day was free to give with as much detail as he thought necessary, his views

on the weather for take-off, route out, target, route home and landing for each operation scheduled. The chairman then checked with Command that he had covered all proposed operations, and called upon each operational Group in turn to state their views, if different from those of the chairman, especially in regard to the Group's own operations. Having heard all the operational Groups, the chairman called upon the Training Groups to give their forecasts for their own bases, in case such were needed for diversionary purposes, and, lastly, asked the C.F.O. (Central Forecasting Office) for their remarks on what had already been said. The chairman then dictated a summary of the opinions thus expressed, which having been agreed by all concerned, was presented to the C.-in-C. and all A.O.C.s interested, as the agreed Command forecast on which the final (flight) planning of operations should proceed. It was also teleprinted from Groups to operational stations for their own planning purposes. During winter, a second routine conference was held in the afternoon, at which the same Chairman examined the first summary in the light of later information, which might include a reconnaissance report, and, if necessary, conducted another discussion and prepared a second summary. If anxieties arose concerning the weather, any Group was free at any time to ask Command or the Chairman to call a special conference.

Forecasts throughout Command, right down to the pilots and crews, were all based on the latest agreed summary, so that all confusion of thought and action was avoided. Only such centralised forecasting could ensure all possible help to aircrews and the co-ordination of effort. The inclusion of C.F.O. gave the Command the benefit of the advice of the most experienced forecasters and of data received too late at C.F.O. for broadcasting before the conference. From 1943 the forecasting centres at H.Q. Fighter Command and H.Q. Eighth Air Force, U.S.A.A.F., listened in to the conferences and found the weather survey of great use to themselves. In particular, when bombers were using fighter cover, it was most important that the fighters should know what forecasts were given to the bombers.

Initial planning for a night operation was normally made on meteorological advice given to the C.-in-C. at his conference in the Operations Room at 0900 hours. As the result of this conference, Command issued targets and suggested routes to Groups. In their turn, each Group held a conference, with Air Staff and the S.Met.O. present, to discuss every phase of the attack laid on for them, including the weather aspect, and then went back to Command either to agree or to argue about their orders. It was essential that at this preliminary conference at Group H.Q. the S.Met.O. should sum up the situation regarding bases for return, as orders to load the aircraft were sent by Group to Stations immediately after the conference, and the matter of necessary diversions governed the petrol and, therefore, the bomb load. The meteorological situation was reviewed again by Air Staff at Command and Groups following each Meteorological Conference and plans were revised as necessary. Meteorological officers at stations were, in their turn, advised by their Senior Officers at Groups for every operation.

Formation and Development of Upper Air Section

An outstanding feature of the meteorological services for the Command was the development of upper wind forecasting. Improved methods of determining winds and temperatures in the upper atmosphere and the development of

weather reconnaissance over the Atlantic made it possible during the war to construct routine upper air charts for the British Isles and Western Atlantic with much greater precision than had previously been possible.

Prior to March 1943, the upper winds provided to navigators for use in Bomber operations were prepared at each Group Meteorological Office on the basis of the data supplied to them in the teleprinter broadcasts from C.F.O., *i.e.*, on the original observations of upper winds and temperatures supplemented by contours of the 750 and 500 mb. surface. Early in 1943, it was suggested that it would be better for all aircraft taking part in an operation to receive the same wind in order to maintain their position relative to each other. It was accordingly arranged for the C.F.O. to issue the appropriate contour lines from which the upper winds could be derived by the Group meteorological offices on the same fundamental basis and be identical within the limits of accuracy of measurement.

Later in 1943, changes in the nature of the operations made it more important that each navigator should have the wind which would best enable the aircraft to reach the target at zero hour, it being more important that as many aircraft as possible should reach the target at zero hour than that all the aircraft should arrive together at a time other than zero hour. Moreover, it had been found that the variations in the wind deduced from the contours by different Group meteorological offices were greater than anticipated and it had accordingly been agreed that the actual upper winds for the route ought to be issued in addition to the contours. These two computations necessitated much detailed calculation centrally and had to be related to the legs of the course to be followed by the aircraft. As the provision of the details of the forecast required in each of the Groups taking part in an operation was not a duty appropriate to C.F.O., it was decided to establish an upper air section at the Command Meteorological Office, primarily to effect these computations but also to co-ordinate, in conjunction with C.F.O. on whose basic deductions the forecasts were based, the issue of any necessary connections to the forecasts necessitated by the receipt of new information after the forecasts had been issued.[1]

Still greater accuracy was required in 1944, however, so, in view of the lack of data from enemy territory, it was arranged that in operations involving deep penetration into enemy territory values of wind directions and velocity should be determined by selected aircrews and transmitted back to Group H.Q. These 'found' winds were telephoned to Command H.Q. and to C.F.O. at Dunstable.[2] They were then plotted and examined by upper air forecasters at Command and at C.F.O. who discussed the results by telephone in the light of their upper air charts. In this way, more accurate forecast values of wind for the level of the aircraft on later stages of the route were obtained and were broadcast by W/T from Command H.Q. to the aircraft at pre-arranged intervals. In some operations, when penetration into enemy territory was too shallow to permit of 'found' winds being used to amend the forecast winds for further stages of the route, the broadcast technique was applied to determining the 'Bombing wind' only. For this purpose, the selected crews would determine the wind over a pre-arranged period such as the period from 45 to 25 minutes before reaching target. These values, transmitted back by W/T, were examined, sometimes at Group only but more often by the upper air forecaster at Command as well, and the 'bombing' wind sent to the aircrews.

[1] A.M. File S.96904.
[2] Bomber Command O.R.S. Report M.12.

Weather Reconnaissance of Enemy Territory—Formation of 'Pampa'

A lack of weather information from enemy territory had been foreseen before the war and aircrews had accordingly been trained to make and record observations in flight. This proved to be a very valuable source of information, and meteorological interrogations by Meteorological Officers at Stations became an established part of the 'debriefing' of aircrews. Information thus obtained of weather conditions over enemy territory was not recent or detailed enough to be of much use for forecasting weather for operations 24 hours later, and an increasing need was felt for a meteorological reconnaissance of such territory. This led to the formation of the 'Pampa' No. 1409 Flight in January 1942. The Flight was transferred to Pathfinder Group in April 1943.

'Pampa' aircraft were used to obtain a broad survey of meteorological conditions over enemy territory in terms of cloud distribution prior to the selection of targets and also to survey conditions over those areas of enemy territory which would assist the meteorologist most in forecasting cloud on routes and at targets after their selection had been made. In the latter case, weather reconnaissance by 'Pampa' was normally made 'up-wind' from the geographical positions to which the forecast would apply. Each reconnaissance route proposed was examined by Air Staff and compromise made if necessary between what was best from the meteorological aspect and what was desirable from the operational aspect (in view of the need to avoid the most heavily defended areas and to ensure that the proposed target was not made obvious to the enemy). Towards the end of the war 'Pampa' aircraft carried thermometers and made vertical temperature soundings at specified points but their main purpose was to report on cloud structure and distribution. This often entailed flying through a layer of turbulent and icing cloud to measure the level of its upper and lower surfaces. Crews were also required occasionally to descend to comparatively low levels over enemy territory to measure the base of low cloud.

Instruction in Meteorology

Meteorological instruction was given to aircrew at the Operational Training Units. It consisted of a revision and continuation of the elementary meteorological instruction which they had received at earlier stages of their training, but was of particular significance as it was at this stage that aircrew first made really long-range flights in operational aircraft and in many cases first realised the full importance of meteorological knowledge. Early in the war, many factors combined to limit the time which could be allotted to meteorological instruction, but by early 1942, the importance of meteorology was being far more strongly emphasised and, as the meteorological staff problem had eased, the meteorological syllabus was expanded. The revised syllabus, issued by Bomber Command in collaboration within the Meteorological Office, included such subjects as Weather over N.W. Europe, Airframe Icing, Cumulo-nimbus Cloud, Upper Winds, etc. Throughout the lectures, the practical application of meteorological knowledge by aircrews was stressed. The importance of recording the weather encountered in flight, and of handing in the report promptly on return, was also emphasised. The formal programme of lectures and talks was supplemented by meteorological films, 'Brains Trusts', quizzes and dummy 'dry swim' exercises which helped to establish the necessary rapport between aircrews and the meteorological service.

The Weather Factor in Bombing Operations

In the opening stages of the war, aircraft of Bomber Command were employed on dropping leaflets over Germany by night, on day reconnaissance behind the enemy lines and on one or two daylight raids on naval vessels. Then, as later, the meteorologist was required to forecast conditions at bases, on route and over the target but, in general, the success of the mission did not depend on the meteorologist to the same extent as in later operations, except in so far as weather was a hazard to aircraft. The facts that leaflet dropping did not require the same precision as bombing, that enemy ground defences were relatively weak and that, during the German advance across Belgium and France in 1940, the weather was uniformly fine, tended to obscure the vital part which meteorology was going to play in the operations of Bomber Command.

Development of the Main Bomber Offensive

In the early days of night bombing, little cloud and good visibility were most desired in order to facilitate navigation and to permit of visual bombing. With the introduction of radar aids, and with increasing opposition from enemy night fighters, aided by searchlights, most of this was reversed. Low cloud or fog over enemy territory, which would hamper the enemy defences, became the more desirable conditions and a target with cloud, fog or haze through which ground markers could still be seen, became most suitable for accurate bombing. In the later stages of the war, the preference for conditions suitable for quick climb near bases gave way to one for good climbing conditions near enemy territory in order to avoid detection of the force by enemy radar devices as long as possible. Throughout the war, however, the ideal conditions were rarely met, and the C.-in-C., when making his decisions, had to aim at taking advantage of those aspects of weather which were favourable to the protection of aircraft and, if possible, to deceiving the enemy as to his intentions. In the selection of targets, deep penetration was usually reserved for those occasions when the weather favoured the attacking aircraft and hampered the defences.

A direct route to a target was unusual. Deviations from the direct route were made for various tactical reasons but sometimes weather influenced the decision. For instance, a devious route might give maximum protection from searchlights and fighters, owing to prevalence of fog or low cloud along it, but a defended area might be included in the route in the knowledge that protection over it by cloud would be a maximum and in the belief that the enemy would expect such an area to be entered only if it contained the target. To suggest that weather was in the main an aid to tactics would be misleading; it was generally a question of adapting the execution of an operation to the forecast weather conditions. In fact, tactical advantage was more often lost than gained from weather.[1]

High Level Sorties

In the last two years of the war, a considerable force of Mosquito bombers, operating from the Pathfinder Group, had its own type of weather problems because the level of flight was between 25,000 and 35,000 feet compared with a ceiling of some 20,000 feet for the main force, and because the high speed of

[1] *See* Appendix No. 5 for an example of the tactical use of weather for bomber operations, and Appendix No. 6 for an account of the meteorological advice given and weather experienced for the first 1,000 bomber raid on 30/31 May 1942.

flight permitted any particular operation to be completed in much less time than was required by the main force. The high level of flight gave the advantage that icing cloud, with tops between 20,000 feet and 35,000 feet could be surmounted by the Mosquito force but not by the main force. The relatively short time required for an operation meant that advantage could be taken of short intervals for favourable weather at base. For instance, as the frequency of fog increases progressively at night, it was often possible for the meteorologist to state confidently that all or many airfields would be free of fog for some three to four hours after sunset while few or no airfields would be free an hour or two later. In short, the provision of meteorological advice for the Mosquito force entailed forecasting the levels of any icing cloud which extended to great heights, as well as the time of onset of adverse weather at bases, with great precision if full advantage was to be taken of every opportunity. High success was achieved. The forecasting work for these operations was done mainly by the forecasting staff at Group Headquarters.

Bomber Support

In order to reduce the mounting losses in Bomber Command, No. 100 Group was formed in December 1943 with the aim of supporting the bombers and destroying the German night fighter defences. Low and high level intruding by specially equipped Mosquito aircraft was carried out against enemy night fighter airfields and German night fighters operating near to and in the main bomber stream. In planning these operations the greatest consideration was given to the weather conditions at enemy night fighter airfields and beacons in order to effect the maximum attrition.

In addition, to disrupt the German night fighter ground organisation, feint attacks were carried out by squadrons of heavy aircraft equipped with special devices. In order to allow the night fighter defences the least possible respite, these feint attacks were carried out regardless of whether there was a major bombing operation. Consequently, the weather at the targets selected for feint attacks had to be carefully considered so that the German meteorological Service would not deem a major raid impossible. As continuity of effort was required, such feint attacks were normally made, provided a limited number of airfields anywhere in this country could be guaranteed for any particular time of return during the night. The type of aircraft chosen for any particular operation was often determined by expected weather conditions. Most of the forecasting work for these operations was done by the forecasting staff at the Groups.

Mine-Laying Operations

Mine-laying operations differed from bombing operations in that the operations were largely controlled by Air Staff at Group H.Q. so that special responsibility rested on the forecasters at Groups, and that the level from which mines were dropped was lower than that for a bombing operation. In the early days of the war, when mines were laid by visual observations and aircraft could descend to a low level in the mining area, poor visibility or low stratus was the primary problem. Later, with the development of radar devices and an intensification of enemy defences, the operations were usually carried out between 10,000 and 15,000 feet, often above cloud or in lanes between cloud. Thus the meteorological requirements for mine-laying operations eventually closely approximated those for bombing operations. Winds at the level from

which the mines were dropped and also between that level and the surface were required as accurately as possible. A routine meteorological reconnaissance flight over the North Sea, from which a temperature sounding at 6° E. was obtained, assisted greatly in this connection.

Daylight Bombing

Before the landing on the Continent, some daylight bombing without fighter cover was practised, the aircraft relaying for protection on cloud cover which was normally required to be continuous over enemy territory. Cloud which caused icing on aircraft could not be used in this way, and there remained available, above freezing level, cloud too tenuous for icing and, below freezing level, sheets of strato-cumulus or frontal cloud. Tenuous cloud above freezing level, if continuous, is normally found on the fringe of a frontal zone. Such cloud becomes denser, thus gaining icing properties, towards the front. It was always difficult to forecast precisely the areas in which aircraft would be free from icing in this type of cloud. The continuity of strato-cumulus cloud is frequently difficult to forecast. Frontal cloud below freezing level is reliable for continuity and its location can be forecast with fair accuracy, but its turbulence makes it unsuitable as a medium in which to fly; furthermore, the base of frontal cloud is usually too low to permit of safe descent underneath it for bombing. Forecasting for daylight operations depending on cloud cover was, therefore, extremely difficult.

With the landing on the Continent, bombing by day with cover from fighter aircraft was practised extensively. This introduced several new features for the meteorologist. For instance, at the point of rendezvous between bombers and fighters, clear air above any cloud that may be present was required in order that the fighters might see the bomber force. Reports by 'Pampa' usually provided the information required about cloud structure and extent for advising Air Staff to decide on the height and position of the rendezvous.

G.H. Bombing

In the autumn of 1944, No 3 Group adopted a special Radar Bombing Technique, known as 'G.G.', which allowed cloud covered targets to be attacked with great precision. In order that damage to aircraft from anti-aircraft fire might be kept to a minimum, cloud covered routes and targets were desired, irrespective of cloud thickness, provided there was a clearance of a few thousand feet between the aircraft and the top of the cloud immediately below. The conditions required were often obtained in early 1945.

Flying Control

A Central Flying Control organisation was formed at Command H.Q. early in 1942, and maintained a close liaison with the Meteorological Section. At the time of take-off, the forecast for bases at the time of return from an operation was often such that the diversion of aircraft outside the Groups to which they belonged was expected. Provisional diversions would then be arranged before aircraft took off, but final decisions could be made later.[1] A direction regularising the giving of meteorological advice for the diversion of bomber aircraft was issued by the Bomber Branch of the Meteorological Office H.Q. in October 1944. The final decision as to the number of its returning aircraft

[1] A.M. File S.64511/III.

which could be accepted in any Group was made by Air Staff of that Group, on the advice of the Group Forecaster who had knowledge of local conditions. Arrangementes for the diversion of the remainder were the responsibility of Central Flying Control, advised by the forecaster at Command H.Q. Hourly charts of observations received from a close network of stations over the British Isles were, therefore, maintained in the Meteorological Office at Command. By examining these charts and the general synoptic situation, the forecaster, conferring as necessary with Meteorological Office at Groups, determined the best areas or airfields for diversion until the last aircraft had landed. Diversion within a Group was arranged by the Group Flying Control Officer on the advice of the Group Forecaster. Diversions for aircraft of other Commands in the British Isles were also arranged by Central Flying Control, thus giving an added responsibility to forecasters at Command H.Q.

Outline of Technical Problems

Weather at Base

The fitness of bases for take-off and return presented the forecaster with two major problems—height of cloud base and visibility. The need for accurate prediction of the height of cloud base increased with any threat of cloud below 1,000 feet. In many cases of very low cloud, fortunately, the threat was confined to parts of the country only. For instance, the spread of low stratus cloud with a drift of air from the North Sea was usually limited to the east of the country. The number of aircraft employed on an operation could then be limited to a figure appropriate to the number of airfields expected to be free from stratus at the time of return. Also, as the formation of low stratus normally increases as the night advances, it was sometimes possible to set a time limit for operations so far as bases were concerned. In these cases, the duration of the operation might be limited by selecting a comparatively short-range target to correspond with the period of safety at bases. All aspects of the problem of forecasting low stratus were difficult, and Air Staff were usually advised to allow a margin for possible error in the forecasts both in area covered and in time of onset. In order to obtain the most useful data for forecasting low stratus with air from the North Sea, a meteorological reconnaissance aircraft made ascents over the North Sea as required. The temperature and humidity of the air were measured at vertical intervals of 25 mb. of pressure (approximately 700 feet).

Another difficult situation for the meteorologist when forecasting cloud conditions at home bases was that of a front with a wide belt of bad weather (cloud base well below 1,000 feet and rain or snow), approaching bases. Since fronts usually approach from the west, great assistance in detecting them and in timing their rate of advance was obtained from routine meteorological reconnaissance flights over the Atlantic.

Even with the best possible network of observational data, the rate of advance of fronts and developments on them are often difficult to forecast, perhaps the most difficult situation for the forecaster in Bomber Command being the one with potentialities for a sudden extension of the bad weather eastwards.

Fog inland is usually caused by radiative cooling on still, clear nights and therefore normally reaches a maximum in extent and intensity in the late night and early mornings. In winter, it may persist all day and in some

situations may form soon after dusk. These characteristics made fog a serious hazard for night bombing operations. Very often the forecaster's problem was to estimate its time of onset in each area of the country. Considerable success was achieved in this, due partly to a study of local conditions by meteorologists both at Group H.Q. and stations. A confident forecast of the time of commencement of fog to the nearest hour could not always be given, but a reliable forecast in terms of the nearest hour or two was usually possible. In the last winter of the war, the installation at a few operational airfields of a heating system for fog dispersal (' Fido ') reduced somewhat the hazard to bomber aircraft, but there were too few installations to permit of a large force being landed simultaneously in fog. Consequently, forecasting fog remained one of the primary responsibilities of the meteorologists in Bomber Command throughout the war, although he might also be asked whether a predicted fog could be cleared by ' Fido.'

Weather on Route

The ideal condition for climb and descent is clear sky ; collision risk renders a long flight through cloud undesirable ; passage through cloud with a high icing index is dangerous. The forecaster had, therefore, to study the cloud distribution and icing risk in any area where a climb or descent might be made. Thick frontal cloud and heavy convection cloud presented the greatest risk from icing and occasionally an operation was prohibited by the dangers of the climb, but usually it was possible for an area to be found away from the worst icing conditions where a climb or descent could be made without the aircraft being unduly hampered.

A route relatively free from cloud at a level of flight was best ; one threatened by thick icing cloud was normally regarded by Air Staff as prohibitive. Usually, thick icing cloud over 20,000 feet is found only in the more active frontal zones or in other conditions of instability. In the weaker frontal zones a lane or lanes free from cloud can usually be found at the higher levels. Pampa aircraft were extensively used for determining the structure of the cloud in areas where there was any doubt about the existence of a passage free from thick cloud. A feature of instability cloud, when not associated with fronts, is its irregular distribution. Thus, in autumn and winter thick convection cloud to great heights arising from instability might prevail over the North Sea, making this route impracticable, but be absent over East England, North East France and South Germany. Alternatively, in summer, thunderstorms might be active over land while there was little cloud over the North Sea. In these circumstances, targets could sometimes be reached by a devious route when cloud conditions on the direct route were prohibitive.

Weather at Target

In the early days of bombing the first essential for success was that the target should be visible from the aircraft, and, therefore, targets were selected in areas where the expectation of clear skies was high. Because of the difficulties of guaranteeing skies free from cloud and haze, however, many failures were inevitable so long as a visual target was required for success. With the development of navigation aids and the Pathfinder technique, the stage was gradually reached when success in bombing operations could be achieved without identifying the target visually. While this relieved the meteorologist of some

responsibility, he was still required to give as detailed a picture as possible of cloud conditions in the target area. With Pathfinder technique, which depended on the use of flares for marking, the Air Staff needed to know whether the cloud was so thick as to prevent any light from ground markers being seen from above the cloud or, alternatively, whether a lane free from cloud would exist at the level of the aircraft, of sufficient depth to permit sky-markers being used instead. The number of confident forecasts of conditions in which ground markers or sky-markers could be seen was obviously much greater than the number of confident forecasts for visual targets. Information brought back by Pampa aircraft was invaluable in this connection, although the observations were necessarily made some four hours or more before the attack. On some occasions, the meteorologist could be reasonably confident that those cloud conditions found ' up wind ' from the target would prevail over it at the time of attack, but usually advection of cloud without change of structure could not be used as a basis for forecasting and normally development had to be taken into consideration. When the only development to be considered was diurnal variation arising from heating by day and cooling by night, fair success could be achieved, but when changes arising from development in the isobaric field had to be superimposed, the forecast was often given with less confidence.

Many cold fronts advancing across Europe have a narrow belt with little cloud and good visibility close behind the frontal zone. Advantage of this situation was frequently taken to obtain a target with good visibility and little cloud. The danger in the situation was the need for great accuracy in timing the rate of advance of these fronts. If the front advanced more slowly than expected, or unforeseen wave development took place on it, the worst possible conditions might occur at the target, *i.e.*, thick cloud to great height instead of clear skies. Pampa aircraft were used until the last possible moment consistent with final planning before take-off, as an aid to determining the rate of movement of such fronts as well as to detect evidence of wave development on them and any change in cloud in the fair weather belt behind the fronts.

Aurora and Magnetic Storms

Aurora and magnetic storms affected operations in two ways. Aurora could give a brighter background in one part of the sky than another against which aircraft might be silhouetted and so rendered more readily visible to enemy fighters. Wireless communication with aircraft could become difficult during magnetic storms. Following a suggestion that unduly heavy losses of aircraft during a raid on Hamburg might have been partly attributable to a reported brightness in the north sky believed to be caused by aurora, the Director of the Meteorological Office examined the possibility of assisting Bomber Command by giving forecasts of the phenomena, but it was decided that forecasting the onset of these phenomena, a given number of hours ahead of the event, was impracticable. Observations of the intensity of aurora when seen in Iceland and North Scotland and reports of any intense magnetic disturbances were noted at Eskdalemuir, transmitted to Bomber Command, and the information was passed to Air Staff when an operation, which might be affected, was being planned. Actually, operational plans were not modified on any occasion after receipt of such information and the importance originally attached to the matter gradually diminished.

CHAPTER 5

FIGHTER COMMAND

At the beginning of the war, the meteorological staff in Fighter Command consisted mainly of ' Interpreters,' *i.e.* junior staff who made observations and transmitted them to the collecting centre at Group H.Q., and obtained from the parent forecast centre any forecasts required. They also ' interpreted ' these forecasts to those who asked for them. These interpreters constituted the staff of a number of Type 4 meteorological offices located at the Command and Group H.Q. and at a number of stations. Forecasting officers had not been provided, mainly because of the short-range of fighter aircraft at that time and the localised nature of the meteorological requirements, but, on the outbreak of war, the meteorological sections at Nos. 11, 12 and 13 Groups were raised to Type 1 by the provision of a Senior Meteorological Officer and the addition of forecasters for a 24-hour forecasting service. These Type 1 meteorological offices continued to meet the requirements of the Group H.Q. and their sections throughout the war.[1]

As new Groups were formed and staff and accommodation became available, more Type 1 offices were introduced, *i.e.* at Nos. 10, 9 and 14 Groups in August, September and November 1940 respectively. Forecasting facilities were not provided at the Command H.Q. itself until December 1940 when operation ' Albino ' was started, and in March 1941 a Senior Meteorological Officer was appointed. To meet the requirements of Fighter Command H.Q., a full Type 1 office was established in May 1942 and thereafter a continuous 24-hour forecasting service was maintained. Early in 1941, measures were taken to build up the night-fighter organisation in the Command and, consequent upon the resulting need for ' on-the-spot ' meteorological advice, the Type 4 offices at night-fighter sectors or sector airfields were each supplied with two independent forecasters, *i.e.* Type 2 facilities were provided at night.[2] Thus the meteorological organisation in Fighter Command eventually consisted of Type 1 offices at the Command and Group H.Q., Type 2 offices (at night) at the night fighter airfields and at some stations where Type 3 or 4 facilities were inadequate, and Type 4 offices elsewhere.

The main duty of the Senior (later Chief) Meteorological Officer at the Command H.Q. was to advise the C.-in-C. and to provide the meteorological information required at Command H.Q., also, in consultation with Meteorological Office H.Q., to co-ordinate the meteorological work in the Command as a whole. He also acted as meteorological liaison officer with A.A. Command and the Royal Observer Corps. When the ' Intruder ' Operations Room was established at Fighter Command H.Q. the S.Met.O. attended the daily planning conference and visited the ' Intruder Controller ' each night when operations were undertaken, to discuss serviceability of airfields for return, especially when diversions were contemplated. The S.Met.O. at a Group H.Q., in addition to being the meteorological adviser to the A.O.C. and Air Staff, was administratively responsible for the Type 2 and 4 offices at stations in the Group, each

[1] A.M. File S.65301. [2] A.M. Files S.70938 and S.70939.

of these being connected to the Type 1 office by meteorological teleprinter where practicable. The meteorological offices at Group H.Q. had responsibilities additional to those within the Group itself inasmuch as they were responsible for a number of Type 3 or 4 offices in other Commands. For example, the Type 1 offices at 9 and 10 Group H.Q. were responsible for supplying the advice and guidance required by meteorological offices at Training stations in north-west and south-west England respectively, whilst the Type 1 office at No. 14 Group H.Q. met the requirements of several Type 4 offices at Bomber Command and Coastal O.T.U.s in north-east Scotland. The Groups themselves were, on the whole, more concerned with the carrying out of operations than the Command H.Q., hence the forecasters at the Group H.Q. were mainly responsible for providing meteorological information, warnings, etc., for such operations. From 1943 onwards, however, when control of 'Intruder' operations was centralised at Command H.Q., the forecast section under the Chief Meteorological Officer played an increasingly important part in the supply of meteorological advice for such operations and arrangements were made to co-ordinate the forecasts between the various units involved.[1]

While the independent forecasters at the night fighter airfields could give advice without reference to those at Group H.Q., there were, nevertheless, routine consultations between the two and, if necessary, with the Central Forecasting Office also. The assistants at the Type 4 offices were given advice and guidance (by phone or teleprinter) by the forecasters at Group H.Q., and the forecasts issued by the Central Forecasting Office on the teleprinter network ensured co-ordination of the advice given in the Command as a whole.

Expansion of the Command meteorological organisation was most marked during the period of development of the night fighter and intruder operations. In 1943, Army Co-operation Command was absorbed by Fighter Command, and the meteorological services of both Commands were fused into one organisation under M.O.8 at Meteorological Office H.Q. The Type 1 office at Fighter Command H.Q. met the meteorological requirements of the newly-formed Combined Operations Planning Section.

By the middle of 1943, operations in Fighter Command were becoming limited to the east and southeast of England. There was little corresponding decrease in the meteorological services, however, as there were still five operational Groups, all with potential defensive roles maintaining Sectors and forward airfields as before; moreover, of these Groups, No. 10, in the south-west, had an important part to play in the projected landing in France. In November 1943, Fighter Command was renamed Air Defence of Great Britain and a re-grouping of Fighter forces was gradually brought about which reduced the number of Fighter Groups and, at the same time, resulted in certain reductions in the meteorological staffs, assisting incidentally, in providing the meteorological personnel for the forces which were to land on the Continent in the following year. A still greater concentration of operations into the south-east of England followed the landing on the Continent, and by September 1944 the meteorological office at No. 12 Group H.Q. had the sole responsibility for meeting the requirements of all the fighter units in the Midlands and north-east, but by that time, except for two or three stations in East Anglia, the activities of this Group were almost entirely concerned with Operational training. In October 1944, A.D.G.B. was renamed Fighter Command, but the

[1] A.M. File S.87577.

meteorological requirements remained the same. Flying exercises of various kinds were still carried out at the stations in No. 10 Group (which had ceased to take any large part in the fighting after the Normandy landings and the general movement of active Fighter operations to the south-east) thus necessitating the continued maintenance of a Type 1 office at the Group H.Q. Towards the end of 1944, it was decided to amalgamate this Group with No. 11 Group which thereby became responsible for meteorological services for all the Fighter Command units in the south of England.

From the early part of 1945, the tendency was towards diminution of responsibilities, although the forecasting organisation could only be reduced slowly and to a limited extent so long as flying of any kind was still being carried out from the stations concerned. There were no new developments in No. 11 Group, and, in fact, the successful landings on the Continent led gradually to Fighter Squadrons based in this country moving to bases in France and relying for their meteorological services on units of Nos. 83 and 84 Groups which had accompanied the liberation force. To the end of the war, however, squadrons of No. 11 Group were engaged in operations for the defence of cross-Channel sea traffic against enemy attack and continued Intruder operations and the escort of bomber forces to and from this country. From this time, too, with Supreme Headquarters established in France, there was a constant movement of high ranking officers and others to and from the Continent. For this traffic route, forecasts of increasing range had to be supplied both by No. 11 Group and Fighter Command H.Q. This, however, did not involve any further increases in the organisation already established.

Siting of Offices

In the early years of the war, the meteorological office at Command H.Q. was accommodated in the Underground block occupying a corner room in the Operations Room itself. In August 1942, however, as a result of the increase in the work of the meteorological office, the section moved to a hut just near the entrance to the Operations Block. This hut accommodated the S.Met.O., the forecast room and the meteorological teleprinter room, and it was arranged that the duty forecaster should visit the Operations Room with his charts for the personal briefing of the Operations Staff.

At Group H.Q., the meteorological offices were located in or near the Operations Block. The original policy of the Command was that the Type 4 offices at the sector stations should also be housed in the Operations block, but this was not invariably followed in practice. When, in the early part of the war, the sector Operations Room was transferred from the precincts of the sector airfield, it was arranged for the meteorological personnel and the teleprinter to move with it. The meteorological staff continued the observational routine at the new location but the observations of visibility and of cloud height were made on the sector station airfield by the duty pilot and incorporated in the regular reports made by the meteorological staff. The intensification of night fighter operations led to the addition of forecasters for duty at night at the Sector Operations Rooms from which night fighter operations were controlled. At first, weather observations at the night fighter airfields, which were not necessarily the sector airfields, were obtained from duty pilots but meteorological staff were gradually provided to carry out observational and liaison duty at night fighter airfields.

In 1942, the policy of having the forecasters at Sector Operations Rooms was changed; the forecasters and assistants were located at the night fighter airfields. The policy of maintaining a Type 4 office at the sector Operations Room was left unchanged. The policy concerning the provision of meteorological offices at the different categories of Fighter Command stations, at the beginning of 1943, can be summarised as follows:—

Fighter Station.	*Type of Office.*	*Location.*
(*a*) Sector	4	Sector Operations Room (normally remote from airfield).
(*b*) Night Fighter	2	Nighter Fighter airfield (Watch Office)
(*c*) Forward or Satellite Airfield.	—	—
(*d*) O.T.U. Day Fighter	4	Watch Office.
(*e*) O.T.U. Nighter Fighter	2	Watch Office.

The policy concerning (*a*) was not being followed uniformly throughout the Command; opinion was divided as to whether the Type 4 office should be located at Sector Operations or at the sector airfield. The position was therefore reviewed, particularly in respect of the need to ensure satisfactory observations from the main airfields, in August 1943. It was then agreed in principle that the Type 4 offices should be transferred from Sector H.Q. Operations Rooms to Sector Airfields.[1]

Fighter Operations

In the early part of the war, the operations staff at Fighter Command and Group H.Q. required meteorological advice mainly for anticipating and dealing with enemy bombing operations, *e.g.* the regions liable to attack from the weather point of view, the suitability of weather conditions at bases. It was also necessary to ensure that all fighter stations received as accurate forecasts as possible of the upper and lower limits of the layers in which condensation trials were likely to form. With the decline of enemy bomber activity after the 'Battle of Britain', the need to maintain the whole of the fighter squadrons at the ready for defensive purpose was considerably diminished, and several squadrons were assigned to offensive tasks against targets in enemy territory on the Continent.[2] Amongst these was Operation 'Intruder' which consisted of offensive attacks at night against various forms of enemy activity, either known or anticipated, such as 'shooting-up' enemy night fighter airfields likely to be used on nights of our large scale bomber raids, intercepting enemy bombers returning to their home bases, silencing radar detection stations, etc.

At first, these operations were carried out mainly by squadrons of No. 11 Group and the meteorological office at No. 11 Group H.Q. were responsible for giving advice for the selection of the most suitable targets and times and also for issuing the necessary forecasts to the stations for issue to aircrew. In August 1942, however, it was decided to centralise the control of 'Intruder' operations at the Command H.Q. and in September 1942 an 'Intruder' Operations Room was opened at Command H.Q. From that time, the forecast office at the Command H.Q. was responsible for advising on the planning of 'Intruder' operations and for co-ordinating the meteorological advice given at Groups and stations. The S.Met.O., or duty forecaster, attended planning

[1] A.M. File S.65328. [2] A.M. File S.87577.

conferences and in consultation with the meteorological office at Bomber Command H.Q. and the Central Forecast Office advice was given regarding expected weather conditions on the routes/areas to be covered and at enemy night fighter airfields.

'Ranger' operations, which began in June 1943,[1] were low flying intruder operations involving deep penetration of enemy territory by 'free-lance' aircraft flying below 1,000 feet.[2] They were carried out by day and, in the moon period, by night. They differed from 'Intruder' Operations in that they were planned and carried out without reference to known or anticipated enemy activity. The operations were planned according to the conditions forecast at the morning meteorological conference with the 'Intruder' Controller. By 1944, the Intruder Squadrons acted as long distance day and night rangers to airfields on the Baltic, in Norway, Berlin and many other important areas. Many of the night raids were carried out either in conjunction with, or as a diversion to, the attacks by Bomber Command. In order that there should be complete co-ordination with the forecasts issued in Bomber Command when the Intruders were directed to attack enemy night fighters the Meteorological Office at Fighter Command H.Q. held a listening watch on the Bomber Command meteorological conference, and the summaries of these conferences were made available to the Intruder Controller who made his plans accordingly. Conferences were also held by the meteorological office at Fighter Command H.Q. with the forecasters on duty at the stations from which the Intruder aircraft operated. When organising daylight Intruder flights, particular care had to be exercised to ensure that ample cloud cover was available for evasive action to be taken by our aircraft if necessary.

In the spring of 1944, forecasts were supplied by the Meteorological offices at H.Qs. Nos. 10 and 11 Groups to the squadrons of these Groups which were engaged in protecting the liberation forces assembling in the south of England, a task which was then the main responsibility of the Air Defence of Great Britain. Also, during this period, forecasts were supplied by the independent forecasters on duty at the night fighter stations of H.Q. No. 11 Group for the sorties flown by the Group's aircraft to counter sporadic night raids of the 'tip and run' variety by the enemy against London. These forecasters were guided by routine sector forecasts issued by the meteorological office at H.Q. No. 11 Group on their teleprinter network.

At the time of the landing in Normandy in June 1944, Bomber Command began to operate in daylight against tactical targets near the invasion bridgehead and later V1 and V2 sites. The bombers were escorted by fighter aircraft from H.Q. A.D.G.B. and H.Q. 2nd T.A.F. Forecasts for these escort duties were distributed over the operational and meteorological teleprinter circuits to the squadrons concerned. The listening watch on the Bomber Command meteorological conferences provided meteorological liaison between Bomber Command and H.Qs. Nos. 10 and 11 Groups. With the advent of D Day, fighters co-operated with the land and sea forces. Meteorological information for offensive sweeps (over the beach-head assault areas, submarine bases in Brittany and attacks on road and rail communications) were supplied directly by the Type 1 meteorological offices at H.Qs. Nos. 10 and 11 Groups (whose aircraft carried out these sweeps) and were distributed to the Sector H.Q.s and squadrons over the teleprinter networks.

[1] F.C.Op. Inst. No. 11, 1943. [2] FC/S.30938/Ops. 3(C).

Soon after D Day, the enemy used the first of his V weapons in an intensive attack on London. The flying bomb attack was launched in the first instance, with considerable regard to meteorological conditions. Bombs were launched at night into an extensive sheet of stratocumulus cloud. This made interception by fighters extremely difficult. A special forecast, giving detailed information concerning the amount, base and thickness of low cloud was provided to the C.-in-C. H.Q., A.D.G.B. every afternoon, until such time as the enemy abandoned his plan of using cloud for the launching of flying bombs and sent the bombs towards London by day and night with little or no regard to weather conditions. The Meteorological Office was able to help considerably in the determination of trajectories and of launching points by providing data concerning the winds at the height at which the bombs were operated. After the launching sites were overrun by our ground forces, the enemy continued the attack by launching flying bombs at night from aircraft flying from bases in Holland and again made as much use as possible of cloud cover to avoid interception. Special forecasts were supplied to H.Q. A.D.G.B. indicating the weather conditions over the enemy bases and the North Sea. In September 1944, the enemy used the second of his V-weapons—the rocket. Action similar to that taken against the V.1 was not possible, but sustained attacks were made by fighters against suspected rocket launching sites, mechanical transport parks and railway off-loading points. Forecasts were provided for these flights by the meteorological offices at H.Qs. Nos. 11 and 12 Groups.

A number of other operations were carried out by Fighter Command for which special meteorological advice was required. In addition, meteorological facilities were also provided for defence measures associated with the Command, in particular the provision of forecasts and upper air data to A.A. formations and the formation of specialised units in connection with smoke-screening of important centres.

Special Operations

' Albino '

Albino was the code name for the free balloon barrage (F.B.B.) introduced in December 1940 as a defensive measure against night bombing raids on London. The barrage consisted of a large number of hydrogen-filled balloons each carrying a small explosive mine attached by means of about 2,000 feet of thin wire. On being struck by the wing of an aircraft in flight, the wires would run taut over the leading edge, dragging up the mine to explode it on impact. The mine was fitted with a self-destroying mechanism, automatically time controlled, which could be set to explode it after a pre-determined interval depending upon the distance downwind for which it was permitted to remain lethal. The balloon was made to ascend fairly quickly to about 16,000 feet and thereafter drifted downwind between 14,000 and 18,000 feet. The aim was to release some 1,600 balloons in each operation at the rate of 400 per hour. A mobile release party, with the necessary equipment for filling and releasing the balloons and arming the mines, was deployed on an arc centred on the target area and some 20–25 miles from it, in such a position that the drift of the barrage would be over the target. This necessitated an accurate estimation of the direction of drift of the balloons, which depended mainly on the wind at 16,000 feet but also on the mean wind between the surface and 16,000 feet (as this determined the drift of a balloon during its initial rising period). The

main meteorological requirement was therefore, the provision of a forecast of the upper winds so that the release party could be deployed before dusk in a suitable position to launch the barrage should a raid develop.

Prior to the introduction of Albino, which was at first known by the code name ' Pegasus ', the meteorological office at Fighter Command H.Q. had been a Type 4 station, its main function being to supply the Controller with the routine hourly and special weather reports from fighter airfields, but as the decision regarding the operation of Albino was the responsibility of the Command H.Q., it became necessary to provide forecasting facilities at that H.Q. and a meteorological officer was accordingly posted there in December 1940. Immediate steps were also taken to provide additional meteorological teleprinter facilities so that the broadcasts from the Central Forecasting Station could be received in full.

The F.B.B. was operated only when the weather conditions were as follows :—

(*a*) Unsuitable for the use of night fighter aircraft.

(*b*) When the surface wind did not exceed force 5 (otherwise the balloons would be unmanageable during the launchings).

(*c*) When the wind at operational height did not exceed a certain critical speed, in order to keep the barrage sufficiently dense to give a reasonable chance of a contact.

The critical speed at operational height was at first laid down as 15 m.p.h. but, as it was found that winds less than this occurred very rarely, it was increased to 30 m.p.h. after a short time.

The organisation of the barrage release party and the provision of equipment and transport was the responsibility of H.Q. Balloon Command. Notification of an intended operation was required by Balloon Command in the early afternoon of the previous day, *i.e.* nearly 36 hours in advance. Accordingly, at about 1430, a preliminary forecast for the following day stating simply ' positive ' or ' negative ' was issued to both Fighter and Balloon Command H.Q. A negative forecast was given only if the non-operation of Albino seemed to be certain, for preparations were made to operate on every possible occasion. On the day of the operation, a preliminary forcast was given at about 0930. This forecast included general conditions in the London area and the track of the barrage assumed to be launched at such a point that it would pass over Central London. This was to enable decisions to be made as to whether or not to deploy, and as to which of the four sectors (NE, SE, SW, NW, based respectively on the balloon centres at Chigwell, Kidbrook, Hook and Stanmore) should be selected for deployment. A final forecast was given at about 1330 hours ; on this forecast was based the final decisions as to the position for launching within the selected sector. Each sector had two or three positions, each a length of road about 5 miles long in the form of a rough arc centred on the target area. Deployment was complete by dusk and the release party held in a state of readiness throughout the night to release the barrage should the order to do so be given by Fighter Command.

As a check on the track of the barrage, a small number of balloons carrying radio-sondes were released with it at approximately hourly intervals. These indicator balloons were followed by D/F stations at Berkhamstead, Chelmsford and Crawley with a control station at Stanmore, where the track was plotted on a large scale map. From January 1941, a check balloon was always launched

in the early evening as a matter of routine, whether or not the release of the barrage was ordered. It provided a useful check on the wind forecasts, the only other direct guide for which being the Larkhill radio-sonde. This wind finding work was carried out by members of the staff of the National Physical Laboratory.

The operation of Albino in the London area was an experiment, and during the middle and latter parts of 1941 arrangements were made for its operation in the provinces, particularly on Merseyside. The necessity for upper wind observations was largely responsible for the setting up of the wind-finding stations at Liverpool and Downham Market. Owing to the fact that night bombing raids on this country decreased considerably after May 1941, Albino was never again operated.

' Petard '

This was an adaptation of the Albino barrage to the Thames Estuary area and 75 miles eastward, and was introduced in February 1942.[1] It was designed to counter enemy mine-laying and anti-convoy activities. The release areas could be made available either on the south or north bank of the estuary. Conditions were favourable when the upper winds were from a westerly direction between 200° through west to 315°, below 4,500 feet, so that the units were carried down the estuary against incoming enemy aircraft. The units were made to float at lower levels than for Albino, more appropriate to the enemy's mine-laying activities. Release depended on a number of circumstances, including weather and wind conditions in the Thames Estuary area.

No release was made if the wind was more than 25 m.p.h. at the surface (which made filling and handling the balloons impossible) or more than 45 m.p.h. at 4,500 feet. Accuracy of forecasts was even more important than in the case of Albino. Unless there was an easterly wind, which precluded any possibility of release, Petard release squadrons were deployed each morning to selected sites along the north or south sides of the estuary on the basis of a forecast of the night's upper winds, considered in relation to the areas where enemy activity was expected to materialise that night. Any subsequent major amendment of the forecast entailed a last-minute and excessively wasteful second deployment or the cancellation of the operation.

In practice, the forecaster conferred with the Controller at 0930 hours and gave a forecast for that night of winds up to 4,500 feet. The release sites were then selected if winds were favourable. One hour before black-out, the morning's forecast was either confirmed or amended, resulting a corresponding confirmation or possible cancellation of the release deployment. Special arrangements were made with the meteorological offices at Manston and Shoeburyness to telephone the results of their evening pilot balloon ascents to reach the forecaster at Fighter Command H.Q. in time for the evening forecast conference. The operation ceased in October 1942.

' Outward '

This was an experimental, offensive floating minefield which was released in southern England to float over N. France, the Low Countries and Germany when there were favourable high upper winds. Forecast of upper winds, at every

[1] A.M. File S.65301.

5,000 feet up to 30,000 feet over the area, S.E. England and the opposite continental hinterland, were required each morning. The operation commenced in June and ceased in November 1942.

' Mutton '

This operation, in 1941, consisted of laying an aerial minefield (lethal bombs suspended from parachute) in the path of anticipated bombers.[1] The minefield was released from aircraft at 15,000 feet, and all that was required from the meteorological office were forecasts of wind, speed and direction at 15,000 feet before the aircraft took off. The difficulties and uncertainties of making this operation a success resulted in its early cessation.

' Headache '

This was a Radio-Counter-Measure, carried out by No. 80 Wing, by which enemy aircraft flying on radio-beams were deviated from their track. It having been noted that the first attempt by the enemy to carry out a daylight bombing raid on the beam had been made in thick warm-frontal cloud (at Gloucester in April 1942), it was considered that if forecasts of thick frontal cloud or extensive strato-cumulus layers over France and Southern England could be passed to No. 80 Wing for daylight hours, the latter could warm up and get their apparatus working steadily in readiness for immediate use.

By arrangement with the Air Staff and Controller No. 80 Wing, the country was divided into six forecast areas, and from 4 May 1942, at first light each day, a forecast of the occurrence of thick operational cloud was passed to No. 80 Wing. A continuous watch was maintained on cloud conditions and movements throughout the day and revised forecasts were issued as necessary. The forecasts proved very useful and every time a daylight raid on the beam was attempted, the radio counter-measures apparatus was in working order and successfully dispersed the raiders. The most striking success was on 23 May 1942, when 30 enemy aircraft approaching Cardiff ' on the beam ' were scattered all over south-west England without dropping any bombs and one aircraft crashed and was destroyed on the high ground in Devon.

' Practice Quarry '

The aim of this operation was to try out methods of interception of aircraft flying in the substratosphere up to heights of 40,000 feet, to ascertain what R.D.F. cover existed at such substratosphere heights and to exercise the plotting and control organisation in Fighter Command. A Fortress flight was to act as the ' quarry.' It was to fly as far as possible above 30,000 feet, on certain pre-arranged tracks (decided on by Fighter Command H.Q.) which passed over the Group areas of Nos. 9, 10, 11 and 12 Groups. The ' quarry ' was to approach the Group area selected from seaward and aircraft from the Group had to attempt to intercept it.[2]

In the first instance, the trials were to be carried out in daylight and only in good weather, with clear skies and good visibility. The Duty Air Commodore at H.Q. Fighter Command was briefed each night by the Duty Forecaster.

[1] F.C. Op. Inst. No. 81.

[2] F.C. Op. Inst. No. 7, 1942.

After taking into account the upper winds, temperatures and possibility of the formation of condensation trails, the Duty Air Commodore would get in touch with the O.C. Fortress Flight, who had also consulted the forecasting staff at H.Q. No. 10 Group, and would decide which of the pre-arranged tracks was suitable. In order to co-ordinate the meteorological information given to the Duty Air Commodore and the O.C. Fortress Flight, consultations were held each night and morning of the trials, between the Duty Forecaster at Fighter Command, No. 10 Group and Central Forecasting Office. The trials began in March 1942 and ceased in November 1942.

CHAPTER 6

COASTAL COMMAND

Immediately before the war, Coastal Command consisted of three operational Groups and one training Group. The geographical boundaries of the Operational Groups corresponded to those of the Home Naval Commands and the Group H.Q. were established as sections of what were known as Area Combined Headquarters which embraced both Naval and Air Staffs. The Group H.Q. were provided with experienced meteorologists for the supply of forecasts and other weather information essential to operational planning, the exception being the newly formed No. 15 Group at Plymouth which had, as yet, no Group H.Q. meteorological staff. Certain stations within the Groups were also provided with experienced (' independent ') forecasters as the distances between many of the stations and their Group H.Q. made it impracticable to rely entirely on centralised forecasting, especially in view of the limited communications facilities then available. The great increase in tele-communications facilities during the war, later made it possible to replace some of the ' Independent ' forecasters at the stations by ' dependent ' forecasters and to rely more on centralised forecasting from Group H.Q. At Command H.Q. in peacetime, there was normally no meteorological staff except for a Senior Meteorological Officer who acted as technical adviser to the C.-in-C. and as liaison officer between the Meteorological Office and the Air Staff of the Command but there was a forecast room which was specially manned during any Coastal Command exercises.

The rapidly deteriorating international situation made it necessary, towards the end of August 1939, to introduce the extended wartime meteorological services in the Command as agreed by the R.A.F. Meteorological Policy Committee. This involved increasing the staffs to provide for a 24-hour forecasting service at Command and Group H.Q. and at certain operational stations, and also establishing meteorological units at stations which had not been so provided in the peacetime organisation.

Type 1 meteorological offices, with a Senior Meteorological Officer-in-charge and a staff of forecasters and assistants adequate to provide a 24-hour full forecast service, were established at Command and Group H.Q. At Command H.Q., operational decisions were taken in consultation with the Admiralty, and were of much wider scope geographically and made much earlier in point of time. They were based mainly on strategic rather than on tactical considerations and, therefore, could take little account of day-to-day weather. The Senior (later Chief) Meteorological Officer and the forecast staff at Command H.Q. were concerned only to a limited extent in forecasting for set operations. The Command Air Staff, however, maintained a continual survey of Group operations and the meteorological staff had to be prepared at any time to supply information regarding the weather in all the operational areas. In the early part of the war, the Senior Meteorological Officer at Command H.Q. was not responsible for any outstations, but he was later made responsible for the meteorological section attached to the Photographic Reconnaissance Unit at

Benson, Oxfordshire. The Senior Meteorological Officer at a Group H.Q. supervised all the meteorological offices in his Group, and also some offices which did not properly belong to the Group or even to the Command, but which were placed in his charge for reasons of administrative and technical convenience. As each Group H.Q. was responsible for the conduct of operations in its own area, and as operations in different areas frequently had different aims, each Group worked to a large extent independently of the others, and there was no need for direct integration of operations from Command H.Q. The meteorological staff at each Group H.Q. advised its Air Staff with regard to weather conditions for specified operations or on the weather factors which might help to determine the choice between alternative operations, and the Senior Meteorological Officer therefore normally attended the daily operational conferences at the Area Combined H.Q. He also co-ordinated the advice given at the conferences with that to be given at the operational stations to the squadron commanders who were to carry out the detailed operations decided upon at Group H.Q.

Most stations within the Groups were provided with a Type 2 meteorological office, but one or two stations were so near to a Group H.Q. that it was practicable to provide them with a Type 3 office staffed with ' dependent ' forecasters who had to rely on the Group forecasters for their primary forecasts but who were competent to apply these forecasts to the detailed planning of the operations carried out at the station. It was decided at Command H.Q. what operations were required, at Group H.Q. whether or when the operations would be carried out and, at the station, how the operations should be carried out. The station forecaster advised on all aspects of weather bearing on the tactical planning of the flight, *e.g.* assessment of cloud and visibility in the target area and the wind speed and direction at various heights and times along the route. The forecasts were given to aircraft captains on a specially designed form on which the flight was set out in sections with a detailed forecast for each section. As sorties over the Atlantic increased in range, a more elaborate form was introduced. It was also the duty of the station meteorological officer to ' de-brief ' crews on the weather experienced during flight and to maintain a system of warnings at his station for gales, frosts, etc., which might call for special measures to be taken for the safety of aircraft on the ground or for motor transport vehicles.

With the loss of many Continental observations and the almost complete loss, for security reasons, of observations from ships at sea, the synoptic charts sometimes allowed of more than one opinion as to future development. It was necessary, therefore, to provide for some measure of co-ordination of forecasts, and the main forecasts, based on the guidance of the Central Forecasting Office, and issued every six hours at the various Group H.Q., were accepted as a general guide throughout the Command. These were sent by teleprinter to stations in the Group and to Command and to Command H.Q. The Group Meteorological Office was the co-ordinating authority for offices within the Group, partly because an important part of the Group forecaster's work was to advise Controllers regarding the most suitable bases for diversion. The forecasters at Command H.Q. paid great heed to the Group forecasts, as the Group forecasters maintained a close and continuous study of the developments affecting the comparatively limited area of responsibility of the Group, far more so than was possible for the forecasters at Command H.Q., who had the whole

area of coastal operations to keep in view. In practice, the duty forecaster of a station generally prepared his own forecast and when it differed significantly from the Group forecast, the forecasters concerned conferred by telephone and, if necessary, referred to the Central Forecasting Office, so that an agreed opinion was reached and, if necessary, the Group forecast amended.

Group Activities

The three operational Groups of the Command at the outbreak of war were No. 15 Group, responsible for operations in the Western Channel and the South-Western Approaches; No. 16 Group, controlling air operations in the Eastern Channel, the Straits of Dover and the southern half of the North Sea; and No. 18 Group, concerned with operations in the northern section of the North Sea. A fourth Group, No. 17, was not directly concerned with operations but was responsible for the operational training of aircrews in the Command. The stations of this last Group were mostly equipped with Type 3 meteorological offices which were responsible both for forecasting work and meteorological instructions. As the flying exercises in No. 17 Group were carried out independently of any Group direction, there was no need for any centralised forecasting and no meteorological section was established at the Group H.Q.; for administrative and general technical supervision, meteorological units in No. 17 Group were attached to the Type 1 offices at neighbouring operational Group H.Q.[1]

The expansion of the Command affected the meteorological services in all its Groups in varying degrees, but was most marked in Nos. 15 and 17 Groups. To meet the great extension of Atlantic operations, the new Area Combined H.Q. was formed at Liverpool in February 1941, to which No. 15 Group, with its meteorological staff, was transferred. A new Group, No. 19, which included a normal Type 1 Group meteorological establishment, was formed to take its place at Plymouth. From then onwards, No. 15 Group required meteorological advice broadly for operations in the North-West Approaches, while No. 19 Group required advice for operations in the South-West Approaches and the Bay of Biscay. The functions of these two Groups came to differ in more than mere area of operations: this was reflected in their meteorological requirements. No. 19 Group concentrated mainly on attacking submarines leaving or returning to base, but occasionally attacked surface ships at sea and in port, while No. 15 Group was engaged almost entirely on convoy escort duties. The No. 15 Group meteorological office consulted daily with the Naval operations staff at the Liverpool Combined H.Q. on the meteorological aspects of naval operations, and special forecasts were issued for the routeing of convoys and for specified positions in the Atlantic. The meteorological advice required by this Group, apart from return landing conditions, was concerned mainly with visibility and cloud conditions in the neighbourhood of the convoy, regarded from the standpoint of ability to carry out effective search for submarines, but in No. 19 Group, cloud cover had to be considered for protection against land defences as well as for aiming visibility.[2]

One particular responsibility fell on the meteorological officers of No. 15 Group H.Q. from June 1941.[3] Shipping in the eastern Atlantic had become subject, during the early part of 1941, to bombing attacks from enemy aircraft

[1] A.M. Files S.64507, S.64508, S.64509.
[2] A.M. Files S.68898, S.48136.
[3] A.M. File S.69283.

based on Norway and N.W. France. A number of merchant ships and naval vessels were, therefore, equipped with a fighter aircraft which could be launched from the deck by catapult and which was intended, after its attack, to land if possible in Northern Ireland, Scotland, south-west England or Iceland. If the distance of the convoy from any land precluded this, the pilot was to return to the convoy, abandon the aircraft by parachute and be picked up by the convoy. This required constant vigilance by the forecasters at No. 15 Group H.Q., who had to supply at stated times route forecasts from the convoy to the nearest land or, if no land was within aircraft range of the convoy, a wind at 5,000 feet to enable the pilot to navigate his aircraft back to convoy, and the visibility, in order that he should know the distance at which he might expect to sight it. Convoys having this protection had, therefore, to be supplied regularly, every six hours, with the necessary meteorological information, which varied according to their position at sea. No. 15 Group meteorological office was also responsible for supplying forecasts and warnings to various Naval, Army, Air Force and Civil Aviation stations outside the Group organisation and control.

During 1943 and the spring of 1944, the number of stations in No. 19 Group increased rapidly and included one, Dunkeswell, at which American squadrons operated under No. 19 Group control. The meteorological service increased proportionately and from the autumn of 1943, there was an American Meteorological Section at No. 19 Group H.Q. to look after the interests of the U.S. squadrons. There was close liaison between the American and British sections. There was also an American meteorological office at Dunkeswell and, for a time, at St. Eval. Polish and Czech squadrons operated from several No. 19 Group stations and usually had some meteorologists of their own nationality working with the British staff.

From the meteorological point of view, the Coastal Command plans for the Overload operation meant providing forecasts for a larger number of shorter sorties. By June 1944, the number of sorties from stations in No. 19 Group was more than doubled, but most of them were short ones over the English channel. The very poor weather in the summer, the small endurance of many of the aircraft employed and the larger number and great importance of the sorties made this a most difficult period. The mass of work in the forecast office at the Group H.Q. at this time made it mecessary to have two forecasters always on duty. As with the forecast offices at other Group H.Q. in the Command, external commitments, *e.g.* for smoke screen units, A.A. units, artillery practice camps, etc., all involved a considerable amount of daily routine work.

The entry of Russia into the war brought new responsibilities to the meteorological staffs in No. 18 Group.[1] One result of the enemy occupation of virtually all the continent of Europe was the serious limitation of facilities for communication between this country and Russia. Journeys of statesmen and service representatives between the two countries had to be made by air and, at first, by the route between Scotland and Archangel, a flight which might take up to seventeen hours. No regular service was established along this route, but a number of flights had to be made, especially during the earlier period. For the outward flights, conditions at Archangel had to be forecast more than

[1] A.M. File S.73793.

sixteen hours ahead. Information for this area was scanty and arrangements had to be made for local forecasts to be issued from Archangel to this country. For inward flights from Archangel, long range forecasts were similarly issued to that port from this country. The forecasts were drawn up at the Central Forecast Office and, for the outward flights, issued through the meteorological office at No. 18 Group H.Q. to the departure station in the Group where the station meteorological officers undertook the detailed briefing of the pilots and navigators. Another result of Russia's entry into the war was the institution of a considerable sea convoy traffic between British ports and Archangel, necessitating the provision of air cover as far as possible. No. 18 Group was also responsible for supplying the meteorological advice for these operations. This was no more than an extension of the regular forecasts for the Norwegian coast which had long been supplied to squadrons reconnoitring the fjords for enemy shipping—one result of which had been the detection of the *Bismarck* in May 1941 and her subsequent sinking by the Royal Navy—but it was an extension to wide sea areas as distinct from the coast itself. From then onwards, the forecasters of No. 18 Group were continually occupied with the northern convoy routes as well as with operations in the North Sea. In addition, the Type 1 meteorological office at H.Q. No. 18 Group was responsible for a large number of meteorological stations in Scotland, many of which were in other Commands.

Forecasting for flights to Scandinavia required careful thought, the Norwegian coast being a notoriously difficult region for predicting cloud amounts and heights. Fronts moving west to east or east to west are much modified by the mountains and their behaviour is erratic and difficult to assess. Forecasting of cloud conditions over and near fjords demanded careful consultation of all available data. The forecasting of base conditions at stations in the No. 18 Group area also required careful study of topographical effects as there are many local peculiarities of weather in Scotland. The Air/Sea Rescue Service made constant demands upon the meteorological office at No. 18 Group; sorties by this service were flown in the most adverse weather conditions, and the forecasting involved sea and wind conditions in the search area and was of a very exacting nature. Flights between east Scotland and Sweden by B.O.A.C. aircraft were also an important commitment; most of these flights were operated from Leuchars, and the forecasting was done by the Leuchars meteorological office in consultation with No. 18 Group. From 1943 onwards, there were occasional flights by Catalina aircraft to Vaenga and Murmansk, for which flights forecasts were prepared by No. 18 Group in consultation with the Central Forecasting Office and passed to Sullom Voe. Late in 1944, two Halifax squadrons based on Stornoway were used for attacking enemy shipping at night in the open waters of the Kattegat; these attacks were continued until the end of hostilities. Forecasting for these long range night sorties was always difficult and it was necessary for the meteorological officers at Stornoway to maintain a close liaison with the forecasters at the Group H.Q.

Although the meteorological service in No. 16 Group was not involved in such important operations as in the other operational Groups of the Command, it performed an important function throughout the war by providing information for the Navy (in connection with the movements of convoys, mine-laying and sweeping, operation of light coastal forces, etc.), for the

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Army (meteor reports for Coastal defences and A.A. units, etc.) as well as for the R.A.F. itself (action against enemy shipping, air/sea rescue, reconnaissance flights, etc.).

Reports from Aircraft

The expansion of Coastal Command was accompanied by considerable technical developments in aircraft and equipment, but the only aspect of this development which seriously concerned the meteorological staffs was the gradual replacement of the original short and medium ranged aircraft by aircraft of progressively longer ranges until eventually, in 1943, it became possible, using American and other Atlantic bases as well as British stations, to supply convoy air protection over the whole width of the Atlantic. The lack of meteorological reports from enemy and enemy occupied countries, and the cessation of weather reports by radio from Atlantic shipping had a serious effect on the period ahead and the precision with which satisfactory forecasts could be issued. The effect was felt in all branches of the forecast service, but it was particularly serious in Coastal Command, as in No. 15 and later in No. 19 Group, the general direction of sorties was to the west. It was clear that some means would have to be found for supplying observations from over the Atlantic in place of those which had formerly been received from ships. One step was a Western Approaches General Order, issued in February 1940 which instructed all destroyers or sloops to add a weather report to all messages on every occasion when W/T silence was broken in the area west of 70° W. Twenty reports were received in the following month, and the number gradually increased. Another step was to obtain observations from Coastal Command aircraft flying over the sea to the west. The idea of supplementing weather reports from surface stations by observations from aircraft in flight was not new, and aircraft crews already kept what was, in effect, a weather log on a standard form (Form 2330) which had to be handed to the meteorological officer at the landing station on the completion of a flight.

By the middle of 1940, a considerable volume of valuable reports was being received in No. 15 Group and these were distributed throughout the meteorological service. As reports by radio were still forbidden, except when aircraft broke wireless silence west of 10° W., the reports were not available to the forecasters until some hours after the time of observation, a difficulty which was not overcome satisfactorily until 1943. Hitherto, the procedure for obtaining weather information from crews on return had varied from station to station, at some the meteorological officer being responsible for obtaining this information and at others it was obtained by the Intelligence Officer. In all cases, the Intelligence Officer was responsible for filling up a weather section of form Orange (a signal originating from the stations and reporting the results of a returned sortie to higher formations). In the autumn of 1943, this form was revised and the weather section omitted. At the same time, meteorological officers were instructed to be present at all interrogations for the purpose of collecting information regarding weather conditions encountered during the sortie. Such information was then passed from stations to Groups and thence to the Central Forecasting Office over the meteorological teleprinter system. By this time, the reports had developed into complete coded reports, which included estimates of temperature and sea-level pressure, much on the same lines of normal ships' reports. Agreement was also obtained for their

transmission by radio, though with certain restrictions which were essential for the security of the convoy, but this arrangement virtually ceased in 1944 because of more drastic restrictions.

This ruling regarding the interrogation of crews led to consideration of the siting of the meteorological office on a Coastal Command station.[1] Although most of the offices had by then been established in the Operations Block on stations, this siting was by no means universal. The great disadvantage of the Operations Block was that the meteorological observers were unable readily to see the weather conditions, as nearly all Operations Blocks were either underground or protected by blast walls, etc. On the other hand, the siting of the meteorolological office in the Control Tower, or in administrative buildings, whilst allowing for good observation conditions, often left the meteorological officer far from the nerve centre of the station—the Operations Block. In this building from which general operational control was exercised, were generally held all briefings and interrogations, at which meteorological officers had to be present. The matter was discussed in November 1943 and instructions were then issued that all Coastal Command meteorological offices should be situated in the station Operations Block during the period of hostilities. This policy was also generally applied to stations in the Command where Operational Training Units were located.

Meteorological and Photographic Reconnaissance Flights

The reports from operational aircraft of Coastal Command, while of incalculable value to all sections of the meteorological service, were, nevertheless, somewhat sporadic, depending as they did on the exigencies of operations.[2] Early in the war, it was recognised that a basic scheme of regular ocean observations was required, such as could be provided only by aircraft whose primary task was that of meteorological observing. Consequently, in November 1940, three Meteorological Flights of Blenheim aircraft were established, two for observations over the Atlantic and one for observations over the North Sea. These aircraft carried trained meteorological observers and, in addition to making complete observations at regular intervals along a set route, made upper air soundings at the outward limits of their sorties. More of these Flights were later established, and the aircraft were replaced by others of longer range. By September 1943, this Meteorological Service in Coastal Command had increased to five squadrons and two flights totalling 70 aircraft ranging from Halifaxes to Spitfires. The normal meteorological advice given to the pilot and navigator before each flight was supplied for these sorties in the normal way by the meteorological officer of the Coastal Command station just as for any other operational flight, but in the interests of regularity of observation, very much greater weather risks were accepted for these sorties than was the case for the normal reconnaissance operations of Coastal Command aircraft.

Coastal Command was responsible from June 1940 for the administration and operational working of the Photographic Reconnaissance Unit at Benson, the technical direction of which was in the hands of the Director of Intelligence at the Air Ministry.[3] The meteorological staff at Benson at first included only one forecaster, but as operations extended to fill the whole of the daylight hours,

[1] A.M. File S.104224.
[2] A.M. Files S.67591, S.77460.
[3] A.M. Files S.67492, S.64512.

the staff were gradually increased to that of a full Type 1 station with five forecast officers as well as additional staff at Mount Farm and separate staff with the P.R. detachments at other stations. By 1943, the system of supplying weather information for photographic reconnaissance had settled down to a fairly definite routine. The operational staff normally had a daily list of targets of which photographs were required, with an order of priority. In the afternoon or evening a conference was held with the Senior Meteorological Officer and the most likely targets for the next day's work selected. Further discussions were held on the following morning and finally, prior to departure, crews were independently briefed in the meteorological office. On return from a sortie, all crews reported to the meteorological office for interrogation which yielded much valuable weather information as many of the photographic reconnaissance sorties reached far into enemy territory. The results of these interrogations were immediately transmitted to the Central Forecasting Office for use and dissemination. During the last few months of the war in Europe, a detached photographic reconnaissance wing (No. 104 Wing) was also formed at Coulommiers in France. A separate meteorological section was attached to this Wing and was normally manned by forecasting officers on detached duty from Benson.

Weather Factors in Coastal Command Operations

Apart from certain photographic and meteorological reconnaissance units, Coastal Command aircraft normally operated at levels below 5,000 feet, and often below 2,000 feet, so that forecasters were not primarily concerned with high cloud or upper winds but had to concentrate on low cloud formations, low level visibility and winds ; the state of the sea was also frequently required in the forecast. A factor of prime importance was the fitness of bases or of suitable diversion airfields for the return of the aircraft.

General Reconnaissance Flights

Although flights often were made in very poor weather conditions when particular targets were being sought (especially in the later stages with the aid of radar) moderate to good visibility in the reconnaissance area was normally required for flights of this type so that shipping could be spotted and identified, photographs taken of sea lanes, harbours and shipping. The main purpose of the flights was to provide data on which shipping ' strikes ' could be planned. If a choice of areas for reconnaissance was possible, the choice was usually made on the advice of the forecaster who indicated which area was expected to have the best visibility. In those areas, however, where enemy fighter aircraft were known to be operating, cloud conditions on the route and in the reconnaissance area were also of considerable importance, so that full advantage could be taken of the clouds for evasive action. For this purpose, considerable amounts of layer cloud were preferred and, in some cases, where the forecaster predicted very little cloud, sorties were cancelled. In the later stages of the war, cloud cover was less important, as aircraft could be tracked by radar.

Convoy Escort[1]

For this type of operation, it was essential that every sortie planned should, if possible, take place and that aircraft should reach and maintain correct patrol positions. Careful consideration had, therefore, to be given to weather and

[1] A.M. File S.69019.

navigational winds on the route and in the patrol area as well as to possible diversions if bases were likely to become unfit. In a few cases, cancellation of air escort for convoys was followed by enemy attacks on the convoys, so the forecaster had to be particularly confident before giving advice which might lead to cancellation of a sortie. The forecaster had, sometimes, also to provide information on weather expected at German bases from which aircraft might be expected to attack our convoys.

' Strike ' Operations

In the early part of the war, fairly clear weather with good visibility and not too much cloud in the target area were required for strike operations (attacks by our aircraft on enemy merchant shipping or naval units) so that ships could be readily identified and attacked. Later, as opposition from fighter aircraft and anti-aircraft guns increased, mainly cloudy weather, along the routes and in the target area, was preferred so that aircraft could deliver a surprise attack from cloud cover and quickly return to it. It was generally considered that weather in the target area should give a minimum cloud base of 1,500 feet with a visibility of at least five miles and no precipitation.

Later in the war, radar enabled our aircraft to carry out ' strike ' operations at night and in weather which would, earlier in the war, have been considered too bad for any success to be achieved. Such poor weather conditions were sometimes an advantage as they sometimes prevented enemy fighter aircraft from taking off and attacking our aircraft. Although strike operations were very dependent on the weather, the forecaster's task was lightened by the fact that such operations were normally preceded by a reconnaissance, and reports were usually available from the reconnaissance aircraft on the weather in the area and on the route. The forecaster then had to assess the probable changes only in the short period before the strike was delivered although these changes were often considerable : information required from the forecaster depended largely on the type of attack, whether by torpedo, rocket projectile, incendiary or high-explosive bomb. For torpedo and rocket attacks, fairly good weather conditions were normally required so that hits could be seen and photographs taken. In addition, for torpedo attacks, the forecaster was called upon to assess the winds in the target area and state of sea. For bombing attacks, more attention was given to cloud base in the target area in connection with the fusing of bombs. The fitness of base or available diversion airfields for the return of the aircraft was, of course, a factor which had always to be considered.

Anti-U-Boat Operations

In the first stages of the war, submarines were sighted visually and the chance of successful sightings depended largely on weather conditions, namely good visibility and calmness of sea. As U-boats realised their vulnerability in these conditions, they, normally preferred to surface at night and it was suspected from information received by No. 15 Group, then at Plymouth, that U-boats were taking advantage of ' fronts ' for screening purposes. On 8 December 1939, an aircraft was briefed to attack a U-boat but failed to make contact owing to poor visibility in the ' strike ' area. However, the A.O.C. No. 15 Group was strongly advised to proceed with the operation and a flying boat was sent and briefed to try to contact the U-boat on the surface at a time when it was estimated that the weather would clear with the passage of the

'front'. The flying-boat accordingly took off and flew blind in cloud to the strike position where the cloud suddenly lifted and the U-boat was sighted and attacked, but without success. With improvements in the applied use of radar and the advent of the Leigh light later in the war, U-boats could be tracked down in most weather conditions, although fairly good visibility was necessary for the efficient use of the Leigh light at night.

Very long range aircraft were introduced for convoy cover in 1942 with the primary aim of closing the 'Atlantic Gap', an area in mid-Atlantic where U-boats had hitherto been more or less immune from aircraft attack. The extended range of aircraft and, consequently, the areas which had to be covered by forecasts, made it essential both at No. 15 Group and No. 19 Group to have synoptic charts covering a very large area. This involved the provision of additional communications facilities (*e.g.* teleprinter link to Prestwick for reception of North American weather reports) and by the middle of 1943 full Atlantic charts were being plotted regularly at H.Q. No. 15 Group and H.Q. No 19 Group. In May 1943, an interchange of landing forecasts for bases in United Kingdom, Iceland and Canada was begun. Aircraft of No. 15 Group were by then operating almost continuously over very large areas of the Atlantic, and it was found necessary to provide for diversions to Canada and Iceland in the event of bases in the United Kingdom being unfit. Later, the interchange of landing forecasts extended to No. 19 Group, the Azores and Gibraltar.

The Schnorkel.—Until 1944, practically all anti-U-boat operations were based on the fact that a U-boat could remain submerged only for a limited time, having, at some period of each day, to come to the surface, and remain surfaced, in order to charge its batteries and ventilate the boat. It was at these times that sightings, either visually or by radar, were made and attacks followed. Early in 1944, it was known that U-boats were being fitted with *schnorkel*, consisting of a pipe about 16 inches in diameter and showing some two or three feet above the water, through which the air for the diesel engines could be sucked in and the exhaust expelled. By constant use of this device, the U-boat could avoid surfacing during a cruise provided that there was not too much sea or swell.

It was not until the middle of 1944, that aircraft encountered *schnorkels*. The effect of their use was to present an extremely small target for detection, either by radio or visually. Even if sighted and attacked, the U-boat could dive very much more quickly when using its *schnorkel* than when fully surfaced, and the probability of an attack being effective was, of course, greatly reduced owing to the initial depth of the boat below the surface. Moreover, the sighting range by use of airborne searchlights at night was so low as to render this method of attack of very little use. A training drive was introduced with the aim of improving the standard of radar operation so that the aircrew's chances of detecting *schnorkels* would be increased, and to devise and practise new and suitable tactics against such difficult targets. The two main problems from the meteorological viewpoint were the theory of the formation of the *schnorkel* smoke cloud and the forecasting of sea and swell.

A frequent method of finding a submarine which was using its *schnorkel* was by a visual sighting on the cloud of vapour discharged from the top of the *schnorkel*. This was most important as an analysis showed that the average distance from which this smoke was seen from an aircraft was 7 miles, whereas the average distance of sighting the wake of the *schnorkel*, and the *schnorkel* itself were 4½ and 1 mile respectively. The Meteorological Office undertook investigation into the theory of the formation of the *schnorkel* vapour cloud. By using this theory it was hoped that it would be possible to indicate from a meteorological viewpoint the areas in which *schnorkel* vapour clouds would be most likely to form. This was based on the fact that the vapour cloud was probably formed by saturated exhaust gases, which were expelled below sea level and bubbled through the surface layers of water, mixing with the air immediately above the sea surface. In working out the theory, a number of assumptions had to be made, particularly in regard to the temperature of the *schnorkel* exhaust gases after they had been discharged from the *schnorkel* pipe under water and bubbled through the top layers of the water. In order to obtain experimental observations on these matters, the problem was referred to the Admiralty who were making *schnorkel* experiments, but the war ended before the information was available. The subject of *schnorkel* clouds was made more difficult by a suggestion that many of the vapour clouds and the accompanying wakes being sighted and attacked, were not due to *schnorkels* but were incipient water spouts. This view was to some extent borne out by a photograph taken by an aircraft in June 1943, when no *schnorkel* could have existed, which resembled in every way the photographs which were later taken of alleged *schnorkels*. Further search revealed more photographs and descriptions of phenomena resembling *schnorkel* exhaust clouds from earlier years. The Operational Research Branch, assisted by the Meteorological Office, investigated fully all recorded sightings in which the vapour cloud appeared, and it was concluded that only 10 per cent, at the most, of sightings allowed, had been waterspouts.

The effects of sea and swell were important for three reasons: the efficiency of radar equipment against the small target of the *schnorkel* was greatly reduced as the sea became higher, owing to radar 'sea returns'; the efficiency of visual search for *schnorkels* (either with or without vapour) and periscopes was reduced to about one-half in moderate seas and one-quarter in rough seas, compared with that in calm seas; in high seas it became difficult or impossible for submarine commanders to use their *schnorkels* at all. The sea effect was very much more important than the effect of swell. After discussions with the Admiralty, who had been maintaining a swell forecasting unit for part of the war, it was arranged to give daily forecasts of the state of the sea and swell in certain patrol areas to Air Staff at Coastal Command H.Q. These forecasts were prepared by the meteorological officers in the forecast section at the H.Q. In addition, Air Staffs at Group H.Q. were in constant touch with their meteorological offices regarding the state of sea and swell.

Photographic Reconnaissance

The meteorological work for these operations was highly specialised. The P.R. Unit was engaged in high altitude photography, in unarmed and usually single-seater aircraft carrying no wireless equipment, and intricate problems of photography from great heights, navigation and immunity from attack were presented. It was the practice for the aircraft to climb almost immediately to its operational height of 30,000 feet, later increased, and to fly to its target at that height. This required an accurate forecast of the wind at 30,000 feet in order to determine the course to be set both for the outward and the return

journeys. This in itself was a very considerable task, especially in the earlier days, and could not have been met without the direct aid of the Central Forecasting Office.

The problem of obtaining satisfactory photographs from these great heights was almost exclusively a meteorological one, a combination of clear air with absence of cloud at all heights in the immediate area of the target being essential. The forecasters concerned with these problems developed a specialised technique. This was based on careful plotting of the edges of low, medium and high cloud sheets, for which a certain amount of interpolation and judgment were always necessary, and on a calculation of the movement of the same sheets, both from the computed winds and empirically, combined with an assessment of the general synoptic situation from this particular point of view. As the general bomber offensive developed, the list of targets grew steadily and the forecast usually decided the selection of targets for the day. The lists grew at such a rate that it became necessary to use every possible hour for sorties ; in this connection, the Meteorological Officers were given the task of advising with regard to the times of first and last photographic light at the target positions.

The fact that these aircraft were unarmed raised its own problems. If one of them was sighted by the enemy, its only defence against fighter aircraft was its speed. It was, therefore, most important that it should avoid flying at levels at which it might create condensation trails, and the height at which these trails might be expected became, therefore, an integral part of every forecast and was taken into account in the selection of targets.

Collaboration with the Naval Meteorological Service[1]

Throughout the war, close liaison was maintained between the Meteorological Office H.Q. in Kingsway and the Naval Meteorological Service in Berkeley Square. Representatives of the latter were invited to attend all meetings at which matters of interest to them were discussed. This applied particularly to questions of policy and to operational planning. The Naval forecasting centre in the Admiralty was connected to the Meteorological Office teleprinter network and was supplied with all the observational reports analyses and forecasts distributed by the Central Forecasting Office. Naval stations in the United Kingdom at which the Naval Meteorological Service had offices were also linked to the Meteorological Office teleprinter network, received the ETA broadcasts, and reported their observations to the appropriate regional centre.

Joint meteorological offices, manned by personnel of both the Meteorological Office and the Naval Meteorological Service, were established at certain important bases where there were combined naval-air interests, *i.e.*

H.Q. Western Approaches (No. 15 Group), Liverpool.
H.Q. No. 16 Group, Chatham.
H.Q. No. 18 Group, Pitreavie.
H.Q. No. 19 Group, Plymouth.
Gibraltar.
Malta.
Alexandria.
Colombo
Singapore.

[1] A.M. File S.50986.

It was not possible, however, for the Director of the Naval Meteorological Service (D.N.M.S.) to provide staff at all these places, but on the other hand, valuable assistance was rendered by D.N.M.S. in East Africa and the Indian Ocean Islands.

The compilation of naval handbooks describing the meteorological regimes in the various theatres of war was undertaken by the Climatological Branch of the Meteorological Office, to which one or more officers of the Naval Meteorological Service were attached. The Marine Branch of the Meteorological Office concentrated upon the preparation of meteorological charts required for operational purposes. Here again, close liaison was maintained with the Admiralty in regard to the priority of the various regions and of the meteorological elements to be charted.

Both the Meteorological Office and the Naval Meteorological Service were represented on the Combined Meteorological Committee at Washington from its inception in 1943. Instructions sent to these two representatives were co-ordinated in London in advance.

The Director of the Naval Meteorological Service was an ex-officio member of the Meteorological Research Committee, and attended, or was represented at, practically all its meetings. The Naval Meteorological Service was thus kept fully informed of all research and development which was in progress, and were able to propose investigation of meteorological matters of particular importance to them. They were thus able to apply these technical advances to their daily routine at the earliest possible stage.

CHAPTER 7

TRAINING COMMANDS

Flying Training Command

The pre-war plans for the expansion of the Meteorological Office had provided for the growing needs of Training Command and, by August 1939, 16 stations in the Command had a meteorological office. About a half of these were Type 2 offices located at the more important schools where qualified meteorological officers were needed to give instruction in meteorology and advice regarding the flying programme ; the remainder were mostly Type 4 offices.[1]

The Air Ministry had ruled that in an emergency, priority should be given to the meteorological requirements of the Operational Commands, and that, except for Air Navigation and Air Observer Schools, which should be kept fully manned, the meteorological personnel of stations in Training Command could be used to make up the strength of the Operational Commands.[2] As a result of the necessary redistribution of Meteorological Office staff on the outbreak of war, eight meteorological offices in Training Command, mostly at Flying Training Schools, were closed and it was not until the spring of 1940 that personnel and telecommunications became available to allow any appreciable increase to be made in the meteorological service for the Command. Meanwhile, forecasts and warnings were supplied, usually by telephone, by the nearest Type 1 or 2 forecasting office to all the units in the Command at which flying took place.

Towards the end of 1940, it became possible to re-establish some more of the meteorological offices at the Command stations. Following a recommendation by the R.A.F. Meteorological Policy Committee in May 1941, Type 3 offices were provided at all Air Observer Schools, eight of them being provided in 1941. These Type 3 offices were each linked to a Type 1 or 2 office which provided advice and guidance for meeting the meteorological requirements of the schools. The requirements were mainly related to the fitness of bases and the most suitable areas in which to carry out exercises. Most of the schools were in the west of the country, some at stations which had marked local variations of weather due to topography, and it was essential that the forecasts supplied should be as accurate as possible so that no flying time should be lost. Thus, in view of the scanty supply of meteorological information from the Atlantic, the forecasters at the parent meteorological offices, already busy with the meteorological requirements of the formation to which they were attached, had an added responsibility which was quite considerable in spite of the fact that the flights from the training stations were relatively short and did not have to be planned a long time ahead. It was not until late in the war that this burden was eased by the provision of forecasting centres specifically for Flying Training Command units.

By 1942, the Service Flying Training Schools, which had usually been provided with a Type 4 meteorological office, had practically ceased to exist,

[1] A.M. File S.60465.

[2] A.M. File S.46303.

having been replaced by the Advanced Flying Units (Pilot) which were formed in order to acclimatise the pilots trained overseas to flying conditions in this country and to provide as much night flying experience as possible. Adequate meteorological advice was needed to achieve these ends and it was, therefore, decided that when staff could be made available and communications facilities improved, Advanced Flying Units (Pilot) should be provided with Type 3 meteorological offices.[1] A parallel development, the Advanced Flying Unit (Observer) also led to the provision of more Type 3 meteorological offices in the Command.

After the transfer of the School of Air Navigation from St. Athan to Canada in November 1940, a new school was opened at Crange where work on the lines of that previously done at St. Athan was carried on and a Type 2 office was provided to meet its meteorological requirements. This school later moved to Shawbury. A new school, No. 1 E.A.O.S., was formed at Eastbourne at the end of 1941 for the ground training of prospective air observers and navigators. It was provided with a Type 2 office under an experienced meteorological instructor, in order to meet the need for meteorological instruction.

The rapid expansion in aircrew training led to a great increase in the work of the Central Examination Board which had for some time dealt with examination papers relating to the basic training of aircrew. It became clear, however, that a meteorologist was needed to set and mark papers on meteorology (as in the higher schools) and in March 1942, a meteorological officer was appointed as an examiner at the Board. From then, all examination papers relating to basic training in meteorology were set and marked at the Board, but this did not relieve the pressure of work on the meteorological staff at the A.F.U.s nor did it lighten the work of the parent forecasting centres in regard to their responsibilities for advising the Type 3 offices in the Command. Moreover, there was a further increase in the number of such Type 3 offices as a result of the meteorological needs of Glider Training Schools and Advanced Flying Instructor Schools.

One of the main obstacles to providing forecast centres within the Flying Training Command organisation itself was the lack of teleprinter facilities and personnel. As the communications needs of the meteorological services in the Operational Commands were met, and trained forecasters and teleprinters became more plentiful, it eventually became possible to set up parent forecasting centres within Flying Training Command, first at Dumfries (No. 29 Group H.Q.), later at Shawbury and finally at South Cerney. An additional forecast centre had always been needed in the extreme southwest of Scotland, especially in view of the effect of topography on weather conditions in that area and the poor communications to the local Type 3 office, hence the decision to give priority to the installation of a meteorological teleprinter switchboard at Dumfries and to upgrade the Type 3 office there to Type 2 early in 1943 and to Type 1 in 1944. Eventually this forecast centre became responsible for almost all the Type 3 offices in S.W. Scotland and N.W. England, one of the most important being that at Ramsey which supplied meteorological advice to the Flying Training Command Control Centre there ; this centre controlled flights by A.F.U.(O) in the Irish sea area.

[1] A.M. File S.60454.

The move of the Central Navigation School and the associated Type 2 office to Shawbury early in 1944 and, later, the closing of No. 9 Group (Fighter Command) and the associated Type 1 office at the Group H.Q., enabled a forecast centre to be set up at Shawbury, at first as a Type 2, and later as a full Type 1 office. This took over fifteen Type 3 offices in the N.W. Midlands and N. Wales, but it was not until early 1945, when the Type 1 office at H.Q. No. 10 Group (Fighter Command) disappeared, that a forecasting centre was set up at South Cerney to take over Type 3 offices in the south-west.

The meteorological service in Flying Training Command, owing to considerations of geography and communications, never developed into an organisation resembling the functional organisation of the Command itself as in the Operational Commands. That it was possible to build up in the Command a meteorological service at all adequate to meet the requirements of the various schools and units was due largely to W.A.A.F. meteorological officers who first became available for posting to non-operational stations about the middle of 1942 and who eventually replaced the male meteorological officers at most of the Command stations. The growth in the number of meteorological offices in the Command during the war was always a compromise between the ideal and what was practicable from the viewpoint of the supply of trained staff and adequate communications.

Empire Air Training Scheme and Transferred Schools

In the first months of the war, the Director of the Meteorological Office and the Controller of the Canadian Meteorological Service discussed how the two services could best meet the meteorological requirements of the Empire Air Training Scheme.[1] As a result, equipment and syllabuses used at the R.A.F. Cadet College, the School of Air Navigation, the School of General Reconnaissance and the Flying Training Schools were sent to Canada and, as far as possible, the meteorological instruction there was identical with that in the United Kingdom as were the chart plotting, briefings and the issue of forecasts. It was agreed in the summer of 1940 that a number of officers from the Meteorological Office should be loaned to the Canadian service to help meet the meteorological needs of the Empire Air Training Scheme until Canadian officers had been trained. Increasing commitments in the United Kingdom in 1940 made it impossible to fulfil this promise, but a liaison officer from the Meteorological Office was attached to the United Kingdom Air Liaison Mission at Ottawa in November 1940. He was responsible for supervising the meteorological units which were sent out with the R.A.F. transferred schools and worked in close consultation with the Controller of the Canadian Meteorological Service.

When the School of Air Navigation was transferred from St. Athan to Port Albert, Ontario, in November 1940, and No. 2 School of General Reconnaissance from Squires Gate to Charlottetown, Prince Edward Island, in December 1940, they were accompanied by meteorological staff. In March 1941, British meteorological staff went with a Service Flying Training School to Kingston, Ontario, and in August with an Air Navigation School to Hamilton, Ontario. The British meteorological staff at the schools consisted of assistants who plotted charts and made routine observations, and forecasters who undertook the issue of forecasts in addition to lecturing duties. An increased number

[1] A.M. File S.58584.

of pupils passing through the schools made it necessary to send some reinforcements from the United Kingdom. It was arranged with the Controller of the Canadian Meteorological Service for the Canadian meteorological training school in Toronto to train some of the British assistant staff in forecasting, so that they could assist the British forecasters. Thousands of pupils were given meteorological training at the four transferred schools.

The schools in Canada, other than the transferred schools, were provided with meteorological staff by the Canadian Meteor Service. The British meteorological liaison officer with the United Kingdom Air Liaison Mission, who returned to the United Kingdom from time to time in order to keep in touch with meteorological developments at home, kept the Canadian staff informed of all new publications and changes in syllabuses and current practice in Britain. In the summer of 1943, a senior officer from Meteorological Office H.Q. visited the transferred schools and discussed with the Controller of the Canadian Meteorological Service the taking over by the latter of the meteorological offices at these schools. The offices at Kingston had already been taken over in March 1943, and a similar transfer of control, which helped the London Meteorological Office to meet its commitments elsewhere, took place at Charlottetown in February 1945. British meteorological personnel remained at Hamilton and Port Albert until the schools there were closed in October 1944 and February 1945 respectively.

Arrangements were also made with South Africa for meteorological instruction and procedure at the schools there to be in accordance with British practice. Training literature was exchanged and in 1940 British meteorological staff were posted with No. 1 School of General Reconnaissance to George and with Air Navigation Schools to Queenstown and Oudtshoorn where meteorological offices giving advice and instruction were set up within the framework of the Dominion organisation. As trained meteorological personnel of the S.A.A.F. became available, they relieved the British staff who were transferred to the Middle East to meet urgent requirements there. There meteorological offices at Queenstown and Oudtshoorn were taken over in 1942 and that at George in January 1943.

No meteorological staff were transferred from the United Kingdom to Australia and New Zealand, but a complete exchange of forms and training literature took place in order to ensure uniformity of practice in teaching methods and briefing procedure.

Instruction in Meteorology

The responsibility for elementary meteorological instruction at Flying Training Schools had been transferred before the war from meteorological officers to officers of the R.A.F. Educational Service who had taken a course in meteorology, but Meteorological Office staff continued to give regular courses of lectures in advanced meteorology at the School of Air Navigation, the School of General Reconnaissance, the Central Flying School, the School of Naval Co-operation, No. 1 Air Observer School and the Cadet College. To meet the requirements of the advanced training courses, and of candidates for First and Second Class Civil Air Navigators' Licences, 'Meteorology for Aviators' had been issued as A.P. 1699 (M.O.432). A pamphlet on 'Meteorology in relation to Air Navigation' (M.O.327) and a 'Short Course in Elementary Meteorology' (M.O.247) were also available.

When new types of schools were developing in the early part of the war, a number of co-ordinated syllabuses of instruction in meteorology were produced either at the schools or at higher levels. As the need for such instruction became more urgent, so did that for co-ordination and consistency, and it was arranged in May 1940 for a senior officer of the Meteorological Office to visit a number of training stations in the Operational Commands and Flying Training Command in order to assess the adequacy of meteorological instruction and to make recommendations for the co-ordinated and orderly instruction of aircrew from the initial training unit to the O.T.U. On the basis of his report, a comprehensive scheme of training was prepared to give a complete and graduated course from the pre-entry to the squadron stage. New syllabuses for all types of training units were subsequently introduced. A publication written round these syllabuses was issued late in 1941 as A.P. 1931 (M.O.448) entitled 'Handbook of Meteorology for Pilots and Aviators': it had a very wide distribution, copies being issued to all training establishments and meteorological offices. A special version of it, 'Notes on Meteorology', was also issued to aircrew and covered basic training in meteorology from the introduction of the aircrew to the subject in the Air Training Corps, through the Initial Training Wing or University Course and Elementary Flying Training School to the Air Navigation or Service Flying Training School. A comprehensive syllabus covering this basic training was printed as Form 2448 and was issued with A.P.1931.[1] The Meteorological Handbook for pilots and observers was revised late in 1942 and a second edition was distributed in 1943.

As had been arranged before the war, instruction in elementary meteorology was given by Education Officers. Such officers were not always available, however, and the meteorological instruction at some units, mostly Service Flying Training Schools, was taken over by Navigation Officers who had received training in meteorology as part of their training. In 1942, criticism of the training in elementary meteorology given to pilots and navigators raised the question of who should give such instruction, but, owing to the shortage of manpower, no decision was reached until 1945 when it was agreed that, when possible, meteorological instruction at Flying Training Schools and Navigation Schools should be given by Meteorological Officers.[2] In June 1944 it was agreed that the Meteorological Office should be consulted when any change was proposed to a syllabus which dealt with training in meteorology. It was also arranged, in order to standardise the setting and marking of examination papers in meteorology, that copies of all such papers should be forwarded for inspection and appropriate action, if necessary, by the Branch of the Meteorological Office H.Q. responsible for the meteorological requirements of Flying Training Command.

In addition to instructing aircrews in meteorology both in Flying Training Command and at the O.T.U.s in the Operational Commands, meteorological staff gave courses of lectures on meteorology, based on appropriate syllabuses, to Glider Training Schools, to the School of Flying Control at Bridgnorth and the Intelligence Officers' School at Harrow.[3] Books, instruments and an appropriate syllabus were also issued to Universities for the University Short Course.

[1] *See* Appendix No. 7 for the syllabus covering this basic training.
[2] A.M. File A.90725/40.
[3] *See* Appendix No. 8 for the syllabus, as revised in 1943, of the advanced training in meteorology given to Specialist Navigators' Courses at Cranage.

A pamphlet, chiefly for the benefit of inexperienced aircrews, and entitled 'How to avoid accidents due to weather' was issued in 1941 as A.P.1980 (M.O.459); a second, revised, edition was issued in 1943. A Cloud Atlas for Aviators, A.P. 1875 (M.O.450) was also produced in 1940 as a simple illustrated cloud guide for aircrews.

Technical Training Command

The meteorological requirements of Technical Training Command were comparatively small and were met either by the provision of Type 4 meteorological offices at a few stations where there was a fair amount of flying and a need for on-the-spot briefing or aircrew, or by the supply of forecasts and warnings by telephone from the nearest Type 1 or 2 meteorological office.

CHAPTER 8

MAINTENANCE COMMAND, MINISTRY OF AIRCRAFT PRODUCTION, AIR TRANSPORT AUXILIARY, AND AIRCRAFT MANUFACTURING FIRMS

The organisations named in the title were all concerned in one way or another with the production and delivery of aircraft for the Services. The meteorological services which they required included gale warnings at manufacturers' airfields and maintenance units for the protection of the large number of aircraft dispersed in the open at these places. Route forecasts and weather reports were required by the ferry pilots for their delivery flights.

The aircraft supply organisation was briefly as follows: Aircraft were tested at the manufacturers' airfields, ferried to a maintenance unit for the fitting of service equipment and then ferried to the service units. The ferry pilots were stationed at ferry pools, each of which served a number of manufacturers' airfields and aircraft storage units. The pilots were taken from this pool each morning in a passenger aircraft which visited the airfields served by the pool, and thence proceeded on their separate delivery flights. The programme of flights was decided each evening for the following day at H.Q. No. 41 Group, on the basis of daily reports of aircraft awaiting collection, and was signalled to the ferry pools. The ferry work was at first carried out by R.A.F. pilots, but in 1940 the civilian organisation, Air Transport Auxiliary, operating under the control of the Ministry of Aircraft Production and H.Q. Maintenance Command, was formed for this work. Until about the middle of 1941, the meteorological arrangements for ferry work were organised in consultation with H.Q. Maintenance Command, but thereafter were made directly with the H.Q. of the Air Transport Auxiliary. The Controller (later Director) of Operations of A.T.A. dealt with the meteorological requirements of that organisation. The Meteorological Office Branches responsible were M.O.6 until September 1944 and then M.O.14 till the end of the war.

Maintenance Command

The Senior Meteorological Office, H.Q. No. 6 Group (Abingdon) arranged early in the war to supply route forecasts to the aircraft storage units at Kemble (No. 5 Maintenance Unit) and No. 3 Ferry Pilots Pool (White Waltham). As a result of this local arrangement, H.Q. No. 41 Group, the Group of Maintenance Command responsible for aircraft movements, asked for the supply twice daily of a forecast covering the British Isles to their units at Kemble, Kirkbride, Filton, Hucknall and White Waltham, which were the only units on the stations and had no easy access to forecasts as had the Maintenance Units on stations where there were also operational or training units. The question was referred to the Meteorological Office and it was at once arranged for route forecasts to be supplied to Kirkbride, Filton and Hucknall from the meteorological offices at No. 4 Group (York), Filton and No. 12 Group (Hucknall) respectively. H.Q. No. 41 Group were told of these arrangements

and were asked to give full details of the requirements of aircraft storage units and ferry pools, including areas, routes and periods for which weather forecasts were required. Just before this, however, H.Q. No 41 Group had pointed out to H.Q. Maintenance Command that aircraft movements were considerably delayed by difficulty in obtaining weather forecasts over congested telephone lines and asked if the Meteorological Office could transmit a daily report on weather conditions throughout the country to all units in the Group. On the instructions of H.Q. Maintenance Command,[1] they put their case at the next meeting, on 30 April 1940, of the R.A.F. Meteorological Policy Committee at which D.M.O. pointed out that the general report asked for would be inadequate if ferry pilots flew long distances for which route forecasts would be necessary. The Committee agreed[2] that ferry pilots should have the utmost possible meteorological information and ruled that D.M.O. should discuss the matter with Mainenance Command and the Directorate of Signals.

H.Q. Maintenance Command were invited in June 1940 to discuss their requirements with the Meteorological Office, but the meeting was postponed as the ferry pools were being reorganised and Maintenance Command preferred to wait until further information was available. Meanwhile, the problem was discussed with the Directorate of Signals in connection with the formation of No. 14 Group at Inverness and the Central Control for Delivery and Mail Flights at Gloucester.[3] It was agreed that Maintenance Command units in the Cotswold area should receive weather information by teleprinters connected to the Gloucester switchboard, and that further examinatian of meteorological staff requirements must await discussion with Maintenance Command. The position in August 1940 was as follows :—

Ferry Pools and Aircraft Storage Units at stations with a meteorological office operating	7
Ferry Pools and Aircraft Storage Units at stations with a meteorological office operating, but teleprinter not yet installed	2
Ferry Pools and Aircraft Storage Units with no meteorological office but teleprinter installed	8
Ferry Pools and Aircraft Storage Units with no meteorological office and no teleprinter	9

A representative of H.Q. No. 41 Group visited the Meteorological Office in October 1940 and explained that pilots flew from a ferry pool to an aircraft storage unit and thence to any R.A.F. station, or from a ferry pool to contractors' airfields and thence to aircraft storage units, the ferry pool generally being located near the airfields it served. It was agreed that route forecasts and reports should be given to the pilot before leaving the pool and that he should receive further information at the aircraft storage unit. This would be done by giving the pilot at the pool a written forecast which he could hand to the meteorological officer at the aircraft storage unit for any amendments, or if there was no meteorological office at the aircraft storage unit, and the pilot was delayed there, he was to telephone the nearest meteorological office. To meet these requirements, Type 3 or 4 offices were to be opened at No. 4 Pool, Prestwick ; No. 14 Ringway, No. 9, Kemble ; No. 8, Hullavington ; No. 3, Hawarden ; No. 9, Aircraft Storage Unit, Cosford ; No. 15, Wroughton ; No. 18, Dumfries ; No. 37, Burtonwood ; No. 51, Lichfield. Meteorological offices already existed or were about to be provided for other purposes at most of the other ferry pools and storage units. Service for the remainder could readily be provided from a nearby meteorological office. The R.A.F. Meteorological Policy Committee accepted the proposed organisation after being warned by the Directorate of Signals that there was bound to be delay in the supply of teleprinters. The agreed arrangements were promulgated in Synoptic Instructions S.38 'Supply of Meteorological Information to Maintenance Command Units', (1st Edition), issued in February 1941.

[1] A.M. File S.60849.

[2] Mins. 8th Mtg. R.A.F. Meteorological Policy Committee.

[3] A.M. File S.60849.

The general principle for the supply of forecasts and warnings were settled by the beginning of 1941 and the organisation grew steadily, without fundamental changes, until V.E. day.

Snow, frost and thaw warnings in 'Nebular Code' were issued to maintenance units of all kinds by the nearest meteorological office from December 1941. A few units from which convoys of lorries left for all parts of the country were given warnings for the whole country, but most received only local warnings.[1]

Ferry Pools

Maintenance Command forwarded to Air Ministry in April 1941 a request by the A.T.A. H.Q. at White Waltham for a meteorological office to be opened at a new ferry pool at Pershore and for reports to be made available between Gloucester and Ternhill. The R.A.F. Meteorological Policy Committee were told on 27 May 1941 that Maintenance Command were satisfied with meteorological arrangements but that the A.T.A. wished to discuss certain complaints with D.M.O. In August 1941 Maintenance Command informed the Meteorological Office that all ferrying had been taken over by the A.T.A. Thereafter, all meteorological arrangements for ferry pool were made directly between that organisation and the Meteorological Office. The meteorological requirements of the A.T.A. were formulated by the Controller of Operations.

The first meteorological office for a ferry pool was opened at Prestwick in April 1941, its primary purpose being to provide landing forecasts for aircraft ferried across the Atlantic, and to collect reports from their pilots on conditions met in flight for onward transmission to the meteorological office at Overseas Air Movements Control, Gloucester. The transatlantic work soon took up the whole time of the Prestwick meteorological office and in July 1941 the service for the ferry pools there was taken over temporarily by Abbotsinch. Although a Type 1 office was opened at Prestwick to serve the Atlantic ferry service, it was found impracticable for it to meet the ferry pool needs, and a Type 3 office was opened at the ferry pool in December 1941.

From the middle of 1941, meteorological offices were provided at a number of new ferry pools which could be adequately served by existing offices, although in several cases the opening was delayed by the difficulty in providing teleprinter connections. A number of other ferry pools—Kemble, Hullavington and Hatfield—were closed and the meteorological facilities withdrawn.

During this period, the provision of meteorological facilities came to be regarded as an important part of the ferry pool organisation. At Hawarden, for example, the meteorological office also served a Fighter O.T.U. and

[1] A.M. File S.60849.

difficulties arose, as at a number of other places, regarding the correct location of the office, as the Fighter O.T.U. was two miles distant from the ferry pool. It was agreed eventually that the meteorological office should be located in the ferry pool buildings as the ferry work was more urgent than training flights. Similarly, the move of the ferry pool from Luton to Thame, planned for early 1943, was delayed until May 1943 by the difficulty in providing meteorological communications at Thame.

Revision of Earlier Procedure

It was decided in December 1942 that a revision of S.D.I. S.38 was necessary for the following reasons :—

(*a*) The Meteorological Office could not be told too much in advance the actual routes to be flown on a particular day.

(*b*) New arrangements had been made whereby, if a pilot was held up at an aircraft storage unit by bad weather, another pilot from a nearby pool would carry on while the original pilot would be given another delivery job in the direction of his own pool.

(*c*) It was rarely practicable, nor was it always necessary, to give every pilot a written forecast.

(*d*) It was simpler for the pilot at an aircraft storage unit to ask for a fresh forecast than to read out an old one and ask for amendments.

(*e*) Flights rarely exceeded one hour in duration. A revised instruction, agreed with Maintenance Command, the Directorate of Aircraft Production (M.A.P.) and H.Q. A.T.A. was issued in February 1943.[1]

Meteorological officers at ferry pools had been asked to send to H.Q. their ideas on the pictorial display of weather information at ferry pools, and consideration of their replies led to the issue of the following instructions for a standard type of display :—

(*a*) Synoptic charts to be drawn on form F.2213N for 0100, 0400, 0700, 1000, 1300, 1600 G.M.T. using, if necessary, Baratic Messages from the Central Forecasting Office for the 0100 chart.

(*b*) Hourly charts on talc or kodatrace superposed on F.2241 to be prepared as required.

(*c*) To assist in the evening discussion with the C.O. of the pool on the next day's ferrying, the 0100 pre-baratic chart to be drawn and the situation discussed with the parent station.

(*d*) (i) Fronts to be shown in standard colours.

(ii) Areas of fog, mist and precipitation to be shaded in standard form (M.O. 2459).

(iii) Areas of over 5/10 cloud at below 800 feet to be hatched in red.

(*e*) An 'Actuals' board to be maintained for selected stations showing times of observations prominently.

(*f*) ETA forecasts, etc., to be readily accessible.

(*g*) Standard set of forecasts for routes flown from the pool to be obtained daily from parent station, and the parent to advise on revision, as necessary.

[1] *See* S.D.I.(S) No. 38.

(*h*) Time, starting point and route for each flight to be obtained to ensure that if one of the standard route forecasts did not apply, a special one would be obtained.

(*i*) A separate column to be ruled in enquiries book for pilots to enter initials indicating receipt of a route forecast.

In January 1943 an establishment of two dependent forecasters and two assistants at ferry pool meteorological offices was approved. The A.T.A. had already agreed in May 1942 that there would be no difficulty in employing W.A.A.F. Meteorological Officers at ferry pools and, as a result, nearly all the staff at the ferry pool offices were W.A.A.F. Following the end of the war in Europe, the A.T.A. Organisation gradually closed down. The ferry pools and associated meteorological offices at Thame, Cosford, Kirkbride, Hamble and Prestwick closed between April and December 1945. The Air Transport Auxiliary ceased to exist at the end of 1945 and ferry work was taken over by the R.A.F. (No. 41 Group Maintenance Command).

Aircraft Manufacturing Firms

The Meteorological Office War Organisation had laid down that weather forecasts and reports were only to be given in war to authorised Service personnel or to such representatives of public services as might be authorised by the Director. Although various other Government Departments had been approached on this matter before the war, no arrangements were made for supplying weather information to aircraft manufacturing firms, and immediately after the outbreak of war requests for forecasts for specific flights were received from them at a number of meteorological offices which were then authorised by teleprinter to supply the information required. The general principle of the supply of meteorological information to these firms was raised in September 1939 with the Directorate of Intelligence and the Chief Overseer of Aircraft Production. It was decided that route forecasts for specific flights should be provided only as and when requested, but that no routine forecasts or warnings should be supplied. The Chief Overseer provided the Meteorological Office with a list of firms to whom forecasts should be given on request.

The British Aviation Insurance Company asked in November 1939 for gale warnings to be given to aircraft manufacturers to enable them to take extra precautions, when necessary, to safeguard aircraft dispersed in the open. The Company were asked to supply the names of responsible officers of the firm to whom the warnings could be given, but appear not to have replied to this. The Company renewed their request in March 1940 and the matter was then referred to the Directorate of Aircraft Production. The latter asked that warnings should be given to the officials responsible for flying and for the safety of aircraft at contractors' airfields, and provided an up-to-date list of firms. In June 1940, each of the 37 firms on the list was asked to name a responsible official who would receive warnings in code ; the secrecy of the information was emphasised. The supply of warnings began in September 1940, the warnings being issued in TELMET CODE from the nearest meteorological office.[1]

Forecasts for M.A.P. Overseers

The Chief Overseer Aircraft Production, Ministry of Aircraft Production, asked in January 1941, to be provided with a daily weather chart to enable

[1] A.M. File S.1828.

him to issue, or not, the necessary instructions for moving aircraft from factories and, if necessary, put into effect the arrangements for Fighter Command to provide pilots for ferrying aircraft from factories which accumulated a large number of aircraft during a spell of bad weather. It was explained that such a chart would be inadequate for the purpose and it was agreed :—

(*a*) That he would be supplied daily with a copy of the morning aviation forecast and the small chart (A.M. Form 1300 covering British Isles) duplicated daily at Victory House, and

(*b*) that the Meteorological Office would arrange for forecasts to be supplied to M.A.P. overseers at aircraft firms. The appropriate meteorological offices were instructed to supply forecasts by telephone in TELMET code to the overseers in question at times to be arranged locally. The list remained the same with only minor amendments until the end of the war.[1]

Technical Information for Ministry of Aircraft Production and Aircraft Firms

Technical weather information supplied to M.A.P. and aircraft manufacturing firms included readings of upper air temperatures and humidities for the correction of data obtained on test flights, and replies to enquiries regarding conditions to be expected in various parts of the world in connection with the design of aircraft and aircraft equipment.

Upper air temperatures were supplied from before the war to Rolls Royce engine testing flight, Hucknall, for correction of engine test flight results. From March 1942, the temperatures and humidities observed over Boscombe Down were supplied to the Bristol Aeroplane Company for the same purpose. In August 1942, at the request of M.A.P., it was arranged for wind and temperature readings at the 1,000, 950, 900, etc., up to 200 mb. levels, with corrections to I.C.A.N. altimeter readings to be sent by telegram in code from Dunstable to any aircraft and engine manufacturing firms on telegraphic request from the firm. The Supermarine Aviation Co. (branch of Vickers Armstrong) received the information as a matter of routine from March 1943. Post-factum values of air density at various levels over East Anglia were supplied to the Orfordness Research Establishment on request for use in bomb ballistic trials.[2]

A considerable amount of climatological information was supplied to M.A.P. by the Investigation Branch (M.O.15(I) later M.O.9) of the Meteorological Office. For example, standard atmospheres were provided for sub-arctic and tropical zones supplementing the international standard atmosphere for use in the design of aircraft, engines and instruments; also a meteorological section was prepared for inclusion in A.P. 1441a 'Aircraft Operation and Servicing under Low Temperature Conditions.'[3]

The Meteorological Office worked in close collaboration with the Telecommunications Research Establishment of M.A.P. on meteorological effects on the propagation of ultra-short waves.

The Royal Aircraft Establishment asked in February 1941 for help in designing a true height computer for use in the stratosphere. Following this request, it was suggested that it would be better for the Meteorological Office to prepare a table of corrections to be carried by the Navigator. At a meeting

[1] A.M. File S.69131.
[2] A.M. File S.104287.
[3] A.M. File A.273158/41.

in October 1941, in the course of which it was explained that the required accuracy was within 500 feet at heights of 30,000 to 40,000 feet, it was agreed that the Central Forecasting Office should compute altimeter corrections for trials at Boscombe Down. The code word 'ALTICOR' was given to these reports. The corrections to be provided were those applicable to an I.C.A.N. altimeter with sub-scale set at 1013·2 mb. and were to be provided at times to be requested from Boscombe Down. The trials were satisfactory and it was agreed in June 1942 to make trials on the accuracy of Alticor information over the Continent by a photographic method, but difficulties in taking photographs with the required degree of accuracy were met and the trials do not appear to have taken place. In December 1942, Synoptic Divisions Instruction S.90 was issued stating that corrections to I.C.A.N. altimeters set to sub-scale reading 1013·2 mb. could be supplied by the Central Forecasting Office to the R.A.F. and aircraft manufacturers on receipt of a signal requesting Alticor information for specified places, heights and times.

The R.A.F. High Altitude Flight was formed at the Aircraft and Armament Experimental Establishment of M.A.P. at Boscombe Down to investigate the problems of fighting and bombing at very high altitudes. The C.O. visited the Meteorological Office H.Q. in August 1940 to ask for the attachment of a meteorological officer to give forecasts for flights and to collect observations taken on such flights for transmission to the Central Forecasting Office. Such an officer was appointed in September 1940, and besides providing immediate forecasts, worked on the statistical analysis of radio wind measurements, the comparison of computed thermal winds with measured winds, and the calculation of humidity in a pressure cabin aircraft. It was clear by the end of 1940 that the main problems were the formation of condensation trails which would reveal the presence of high altitude bombers, and the forecasting of high winds around the tropopause, accurate knowledge of which was vital for navigation. Dr. G. M. B. Dobson, agreed to assist in the work on high altitude meteorology, and the meteorological officer at Boscombe Down was then placed under his direction. Dr. Dobson at once attended to the problem of measuring humidity at high levels on account of its importance in connection with the formation of condensation trails and by May 1941 had devised a frost point hygrometer to be carried by an aircraft. He also suggested a detailed analysis of winds at the tropopause which was carried out at the Central Forecasting Office and published as S.D.T.M., No. 18. In May 1941, pressure from the High Altitude Flight persuaded the Air Ministry to begin routine meteorological ascents to 40,000 feet in Spitfires at Mildenhall, Aldergrove and Wick and meteorological flights to 40,000 feet in a Spitfire of the High Altitude Flight at Boscombe Down began in December 1941. The readings taken were distributed for general forecasting use as well as being used for the special investigation into high altitude meteorology. In September 1941, a report by the meteorological officer at Boscombe Down, 'Notes on the Upper Air Ascents at Boscombe Down and the Upper Winds at Larkhill and Liverpool', was published as High Altitude Flight Report No. 16, A and A.E.E. Report 764/16. The work on high altitude meteorology was later directed by the Meteorological Research Committee.

Meteorological Instruction for A.T.A. Pilots

It was pointed out to the Controller of Operations, A.T.A., in September 1942, that reports from meteorological officers at ferry pools showed that A.T.A.

pilots in general had insufficient knowledge of meteorology. In particular, they were inclined to place undue reliance on weather reports (so-called 'actuals') and to neglect route forecasts, and it was suggested that lectures on the subject should be given at all pools. H.Q. A.T.A. agreed. As a result, meteorological officers at ferry pools were instructed to give lectures on 'off-flying' days; the Air Ministry meteorological films were supplied to all ferry pools, and a copy of the Meteorological Handbook for Pilots and Navigators, in aircrew notes format, was issued to every A.T.A. pilot. On the publication of M.O. 459 'How to avoid Accidents due to Weather' copies were sent to H.Q. A.T.A. for supply to ferry pool C.O.s. In 1943, Thame was made a training pool for A.T.A. pilots and it was arranged for the meteorological officer there to give special lectures to pilots under training.

CHAPTER 9

BALLOON COMMAND

Arrangements were made during the crisis of September 1938 for the attachment of a meteorological officer and the supply of weather forecasts to H.Q. No. 30 Group, then the H.Q. of the London Balloon Barrage, should the Barrage be deployed. After the crisis, forecasts and warnings were issued from the forecast office at Victory House to the London balloon centres for training purposes. In the early summer of 1939, some provincial balloon centres began part-time training. Forecasts were supplied to them from the nearest Type 1 meteorological office and an organisation was prepared for a continuous service in the event of war. When the London barrage began, in July 1939, a scheme of continuous flying of one quarter of the barrage, the Air Ministry provided the forecasts, while the Meteorological Officer H.Q. Balloon Command, appointed in April 1939, attended in the operations room when conditions were doubtful.

On the outbreak of war, the supply of forecasts and warnings to all barrages was put on a 24-hour basis. The forecasts, issued four times daily, included a general inference and the following detailed information :—

(*a*) Wind, speed and direction at the surface, and at 1,000, 3,000 and 5,000 feet, with special reference to squalls or strong gusts.

(*b*) Weather, with special reference to thunder, hail, ice accretion and severe frost.

(*c*) Type of cloud and the height of base and top, with special reference to the likelihood of large cumulus or cumulo-nimbus.

(*d*) Visibility.

Warnings of increase of wind or the development of thundery conditions were issued as necessary at any time.

Balloon Command had submitted to the R.A.F. Meteorological Policy Committee in July 1939 that, at the outset of hostilities, a Type 4 meteorological office would be necessary at balloon barrages until the balloon officers had had enough practice in recognising dangerous weather conditions. This request was renewed on the outbreak of war and it was agreed to take a small number of Technical Assistants II from non-operational stations and attach them to the more important barrages which were not adjacent to a meteorological observing station. A second meteorologist was appointed in 1940 to most barrages as more staff became available.

As new barrages were opened, arrangements were immediately made for the provision of weather information. This was often done at very short notice when barrages were set up to counter hostile activity, *e.g.* the sudden transfer in November 1939 of part of the Bristol barrage to counter magnetic mining. Normally, the meteorological data required by the meteorological units with the barrages were obtained by telephone from the most convenient meteorological teleprinter network. A meteorological teleprinter was installed

at the London barrage H.Q. in September 1939, but this was an exception. In November 1941, the Meteorological Office agreed in principle to the provision of teleprinters at other balloon barrages with meteorological staff, and one was subsequently installed at Bristol but the arrangements for withdrawing meteorological staff from balloon barrages, which came into operation in 1942, prevented any general installation.[1]

H.Q. Balloon Command suggested in June 1941 that after all Barrage Control Officers had taken an appropriate training course in meteorology, and arrangements had been made for direct telephone communications between the barrage and a meteorological office at which contact could be made with a forecaster, the meteorological officers at barrages could be withdrawn. Training courses for barrage control officers, of a fortnight's duration, were arranged, and direct telephone lines were installed between barrages and the nearest Type 1 or 2 stations in the autumn of 1941. The meteorological officers were eventually withdrawn from the barrages in January 1942.[2]

When in May 1942, the enemy made the so-called Baedeker raids against cathedral cities and other places of historic interest, mobile balloon barrages were set up at Norwich, Lincoln, York, Peterborough, Gloucester, Ipswich, Chelmsford, Swindon, Isle of Wight, Colchester, Canterbury, Winchester, Exeter and Salisbury, and arrangements made to supply meteorological information to these units over G.P.O. lines in Telmet code. In August 1942, electric cup anemometers were issued to a number of barrages for use of the barrage controllers.

The balloon defences were somewhat reduced after 1942, and in early 1944, most available balloons were concentrated near London in preparation for the anticipated attack by pilotless aircraft. When the flying bomb attack began in June 1944, a very large barrage of 1,750 balloons was set up to the south-east of London. To safeguard this barrage, a meteorological office was set up and two independent forecasters of long experience with balloon barrages were provided at the barrage control at Biggin Hill; a meteorological teleprinter and a telephone tie-line to meteorological office, H.Q., No. 11 Group were installed.

Balloon Command were responsible for the unit which released small free balloons carrying propaganda leaflets. Forecasts of wind direction were prepared for this unit by the Central Forecasting Unit.

Instruction of Balloon Barrage Officers in Meteorological Factors affecting Kite Ballooning

After the Meteorological Officer, Balloon Command, had had time to gain experience of the problems involved, the Meteorological Office issued, in June 1939, to all balloon squadrons, a typescript on weather factors. Lectures based on this were given by the Meteorological Officer, Balloon Command, at all balloon centres but there was not enough time before the outbreak of war for really thorough instruction to be given. A further typescript on ' Meteorological Aspects of Balloon Barrage Operations ' was issued to barrages in the autumn of 1939. This drew attention to the fact that the wind near the ground might become too turbulent for balloons to be hauled down safely before the wind at operational heights became dangerously strong, so that with increasing winds, consideration of hauling down had to be given well before the wind

[1] A.M. File S.57949.

[2] A.M. Files S.57949 and S.65694

at flying height approached the danger level. Attention was also drawn to the problem in showery weather when the wind near the ground might be too turbulent for safe lowering of the balloons when a cumulo-nimbus cloud came near. Early in 1941, a comprehensive publication, ' Meteorology for the Balloon Barrage ' (M.O.M. 407) was drawn up and issued to all balloon barrages and all meteorological offices at home and overseas.

Lectures on meteorology were given as necessary at Balloon Command to balloon barrage control officers, following the introduction of that type of officer in the winter 1939/40. In 1941, in anticipation of the withdrawal of the meteorological staff at the barrages, all control officers received a fortnight's course in meteorology under the instruction of two forecasters of long balloon experience. During the course, demonstrations were given by the National Physical Laboratory High Voltage Department. After the course, control officers spent three days in the parent Type 1 meteorological office which served their barrage before resuming their duties.

The Weather Factor in Balloon Operations

Although warning of the risk of lightning or squalls was not always given in time for balloons to be hauled down, the arrangements were generally effective and, apart from one heavy loss of balloons over East London in September 1939, few were lost because of failure to receive due warning of dangerous weather. In fact, the warnings helped to avoid heavy losses, as is shown by the serious losses suffered by balloons which had to be flown during air raid warnings even if a meteorological warning was in force, and by the heavy lightning casualties suffered by the water-borne balloons flown from barges, as these could not be hauled down except in very light winds.

The value of accurate forecasts to a barrage commander can be realised from the following two points which he and his meteorological advisers had to consider before balloons were hauled down on account of the onset of strong wind :—

(*a*) It is difficult to haul down or put up a balloon in a surface wind of over force 6 (25–31 m.p.h.), which force may be reached at the surface before the wind at operational height reaches a dangerous strength—about 50 m.p.h. If, therefore, prompt action is not taken it may prove very difficult to lower the balloons later when the wind at operational height becomes dangerous; on the other hand, if they are hauled in early it might be impossible to get them up again in the event of an air raid warning, if the surface wind had, in the meantime increased above force 6.

(*b*) If the balloons are left up in the expectation that the wind at operational height will not reach a dangerous speed the balloons will be in serious danger of destruction by lightning if a cold front subsequently passes over the area when the surface wind had become too strong to lower them.

Technical Investigations of Meteorological Factors affecting Kite Balloons

When the Air Ministry arranged in 1936–37 for balloon barrages to be used to defend vital points, it was realised that one of the chief dangers to the balloons would be lightning, and a committee, with D.M.O. as chairman, was accordingly set up to investigate the matter. It reported in August 1938.

In April 1939, a Meteorological Officer was appointed to H.Q. Balloon Command to investigate the meteorological factors affecting kite balloons, organise the provision of forecasts, etc., and to give instructions to balloon officers in meteorology as affecting balloons.[1] This post was filled until May 1942, when the Senior Meteorological Officer, Fighter Command, became liaison officer with H.Q. Balloon Command. The Meteorological Officer, Balloon Command, examined all available records of balloon accidents and saw much balloon flying. The investigational work was facilitated by the introduction, soon after the outbreak of war, of a questionnaire which was completed whenever a balloon was destroyed or damaged. One copy of the complete questionnaire was sent immediately to H.Q. Balloon Command where it was first examined by the Meteorological Officer. Close touch was maintained with the High Voltage Laboratory of the National Physical Laboratory whose staff were engaged on investigations into the possibility of protecting balloons against lightning and providing instrumental warning of the approach of thundery conditions.

A meteorological officer was appointed in July 1940 to the Balloon Department Unit, Cardington, to help in research work on cloud indicators, instrumental detection of lightning risk and the measurement of gustiness with apparatus fitted to balloons. After much useful work, the post was abolished in May 1942 owing to shortage of staff.

Information on the investigation of individual weather factors such as wind and atmospheric electricity is given below :—

Wind : Before the war, the Meteorological officer, Balloon Command, saw as much balloon flying as possible in winds of various strengths. Later, following the deployment of the barrages just before the outbreak of war, much more information on the effects of wind was quickly obtained as, in contrast to peacetime training, when balloon safety was the prime consideration, every effort was made to keep the balloons flying for as long as possible

While the normal barrage balloon and cable were designed to withstand a steady wind of 60 m.p.h., experience soon showed that only quite new balloons could be expected successfully to withstand a wind approaching such a speed at operational height (5,000 feet).

The effects of ground turbulence were specially considered and it was concluded that, in the town exposure in which most barrages were sited, the balloons became unmanageable near the ground in a mean wind of force 6 (25–31 m.p.h.).

The Meteorological Officer, Cardington, investigated in 1941, gustiness of wind by means of a cup and vane anemometer fitted to a balloon cable and recording electrically in a hut on the ground. The anemometers made a contact for every 20 feet run of wind and the time interval between contacts was measured with a rapid time-base recorder. The results, showing much larger gustiness at heights over 1,000 feet than anticipated, were published by the Meteorological Sub-Committee of the Aeronautical Research Committee.[2]

Atmospheric Electricity : The Air Ministry Committee, set up in 1938 to study the effects of atmospheric electricity upon balloons, included representatives of the Meteorological Office, Directorate of Scientific Research, No. 30 Group (Fighter Command) and the National Physical Laboratory. The

[1] A.M. File 796024/38.

[2] Report 5146 T.A.168.

Committee's conclusions were broadly that no action could be taken to protect balloons from destruction by direct lightning stroke but that possible destruction due to burning of the fabric by brush discharge, which was expected to occur on balloons in an intense field, could be avoided by using insulating rigging and non-metallic protective paint for the fabric. For the safety of the crew, the Committee advised that the balloon winch should always be kept well earthed and that on the approach of a thunderstorm all the crew except the winch driver should remove themselves from the winch but that the winch driver would be quite safe in his cab even if the cable were struck by lightning. This last opinion was based on the view that the cab was equivalent to a 'Faraday cage', a view which was confirmed by trial using a high voltage impulse generator at the National Physical Laboratory and, later, in service in the field.

A new Air Ministry Committee on atmospheric electrical effects on balloons was formed in May 1939 and met at intervals until 1941 to review experience.

The Meteorological Officer, Balloon Command, investigated all cases of balloons destroyed electrically, including cases which had occurred before his appointment. He compiled monthly summaries of electrical losses of balloons, with comments on weather conditions, and distributed them to D.M.O.; Superintendent of Kew Observatory; Directorate of Scientific Research, Air Ministry; and the National Physical Laboratory. Special reports were issued immediately when events of particular interest occurred.

When balloon operations began on a large scale, there was little evidence of the relative importance of destruction by brush discharge and direct lightning stroke, but it soon became clear that balloons fitted with insulating rigging and non-aluminised fabric were little, if any, less liable to destruction than those made of aluminised fabric and rigged with steel wire. The question was of much practical importance as aluminised fabric was found to withstand the weather better than fabric not so treated and the steel rigging to be more convenient in use than insulating rigging. The brush discharge theory was further tested by measuring with magnetic indicators the peak currents which had flowed in the cables of destroyed balloons. The magnetic indicators were strips of specially prepared steels fixed at a known distance from the cable. Whenever a balloon so fitted was destroyed electrically, the indicators were sent to the National Physical Laboratory for measurement of the induced magnetism whence the peak current in the cable was deduced. Their use proved that 90 per cent of balloon casualties due to electrical means were due to direct lightning stroke. The results were as follows :—

Magnitude of Current (amperes)	*Number of Cases*	*Percentage of Total*
No definite result	15	11
500– 1,000	19	14
1,000– 2,000	37	27
2,000–10,000	39	29
10,000–20,000	11	8
Greater than 20,000	14	11
	135	100

The 11 per cent of cases listed under no definite result may contain some when there was a direct stroke carrying less than 500 amperes and others in which the magnetic indicator was incorrectly fitted.

Experience in the summer and autumn of 1939 clarified the question of the degree of thundery activity which constituted an electrical danger to balloons. Examination of 400 cases of balloons destroyed electrically showed that in 32 of these, the only lightning strokes which took place were those which destroyed balloons while on a further 52 occasions, lightning seemed to occur only in the barrage area. On the other hand, precipitating cumulo-nimbus clouds were present above the barrage on every occasion but one when balloons were destroyed electrically. The one occasion occurred at Cardington in April 1939 when a balloon was destroyed by a flash from a cumulus cloud which was not giving precipitation and in that case there was evidence that the cloud was near the point of precipitation. It was concluded that precipitating cumulo-nimbus clouds were definitely likely to give strokes to balloons whether or not they had previously been giving flashes. This view was supported by the magnetic indicator statistics which showed that of 135 balloons destroyed electrically when fitted with magnetic links, the peak current in 52 per cent was 2,000 amperes or less. The figure of 2,000 amperes is much less than that which occurs in ' natural ' lightning flashes. Acting on this information, the Meteorological Office devised a scheme in 1940 for forecasting lightning risks to balloons under which one of eight categories of risk was included in every forecast to balloon barrages.

An apparatus for giving instrumental warning of the approach of dangerous electrical conditions which relied on the increase of the electrical current flowing between the earth and cable as dangerous conditions approached was fitted to a few balloons in each barrage. This current consists of a very small steady current due mainly to brushed discharge from the cable, which was found to reach a value of about ½ milliampere in the presence of dangerous conditions, superimposed on which are sudden transient currents which occur when the induced charge on the cable is changed by the sudden changes in the atmospheric electric field which occur when lightning flashes occur. The apparatus was arranged to cause a neon tube to flash and a bell to ring when the steady current reached ½ milliampere or a transient of ½ ampere occurred. The meteorological officers attached to balloon barrages assisted in the development of the apparatus by collecting reports of occasions when the neon tube flashed or the bell rang, and correlating them with meteorological conditions.

A remarkable event which occurred on a few occasions was the complete volatilisation by the lightning current of the steel part of the balloon cable leaving the hemp core undamaged. As, for this to take place, the steel must have been heated to some 3,000° C., the occurrence is an impressive testimony to the short duration of the lightning stroke. Normally the cable transmitted the lightning current without being damaged.

A minor matter which was investigated was that of the explosions which on a few occasions occurred during balloon deflation, one with fatal results. These occurred only during very dry weather and were ascribed to the explosion of a mixture of hydrogen and air by a spark caused by frictional electrification. The use of damp groundsheets and similar measures during deflation cured the trouble.

Ice Accretion : The possibility of ice accretion affecting balloons was realised before any instance of it had occurred and the winter of 1939/40 provided many cases of balloons being forced down to the ground by the weight of ice

on them, or of the valve being opened by the freezing of rainwater in the valve aperture. One remarkable occurrence was the formation on a balloon ripcord of enough ice in weight to pull the cord and rip the balloon.

Strato-Cumulus Cloud : It was important that barrage balloons should not project above the top of a stratiform sheet of cloud as this might betray the location of an objective to an attacking bomber force. The Meteorological Office collaborated in developing apparatus to indicate to the balloon crew whether or not their balloon was in cloud and included information on the height of top of cloud in forecasts and reports. Meteorological Officers worked on the problem at Cardington with the staff of the Balloon Development Establishment and the British Thomson Houston Company until they evolved a satisfactory device late in 1941. The apparatus, described in B.D.E. report K.B./R/216/I, ' The Fine Gap Cloud Indicator ', consisted essentially of two electrical conductors separated by a gap of 0·01 mm.(10u), which is about the diameter of cloud particles, with associated electrical apparatus which produces a radio signal which can be picked up by a radio receiver on the ground and made to operate a warning horn. It works if a single cloud particle closes the gap. Provision is made for clearing off the particle almost at once but the signal persists for about a second. An essential feature of the apparatus is a thyraton valve. A few cloud indicators were fitted in each barrage. The apparatus was also used to measure the height of base and top of cloud for meteorological purposes. Reports were received from the normal barrages and from a few balloons set up especially for providing these reports, which were sent in ' Retina ' code to the Central Forecasting Office.[1]

[1] A.M. Files S.69264, S.76827 and S.D.I.(S) No. 74.

CHAPTER 10

R.A.F. NORTHERN IRELAND

Meteorological Organisation Prior to July 1940

The organisation of the meteorological offices already in existence was little affected during the first months of war. These offices consisted of a Type 2 at Aldergrove, which formed the main centre for meteorological information in Northern Ireland. (It was connected to the meteorological teleprinter system and was engaged principally in Coastal Command work under No. 15 Group, Plymouth), and a Type 3 at Sydenham (Belfast Airport), which met the needs of the Communications flight, a flying training school and miscellaneous operations from that station (it obtained advice and basic information from Aldergrove by telephone). There was also an operational R.A.F. airfield at Newtownards which obtained meteorological information from Aldergrove. The meteorological requirements of the Army, which increased appreciably during this period, were met at first by the Type 2 at Aldergrove which supplied forecasts, Meteorological reports, etc., direct to the Army units. Early in 1940, however, an Army Meteorological Liaison Officer was posted to H.Q. Northern Ireland Division, in Belfast, and thenceforward he formed the channel through which Army meteorological requirements were determined and supplied. Meteorological information for the Navy, principally for the bases at Belfast and Londonderry, was supplied by telephone from Aldergrove.

Formation of H.Q., R.A.F.N.I.[1]

The German invasion of France and the capture of the Channel ports radically changed the military position of Ireland and the possibility of armed raids and local landings by the enemy on any part of the Irish Atlantic seaboard could not be overlooked. As result, a meteorological organisation was called for which could be mobile, rapidly expandable, and with facilities for working in unison with the Eire Meteorological organisation if required. The formation of a mobile meteorological section was agreed in June 1940 and, as a first step a Chief Meteorological Officer was posted in July 1940 to the Air H.Q. which was being formed at Belfast. This officer was to act as meteorological adviser to the A.O.C., and was made responsible for the meteorological requirements of all Services in Northern Ireland, both under the normal conditions of expansion and in the event of mobile field operations. At the same time, R.A.F.V.R. meteorological personnel were posted to Aldergrove in order that a unit might be formed and placed in the field with the utmost speed.

Mobility Plans and General Organisation

It was expected that, in the event of active land operations, the Air Forces would be divided into a forward element moving in the field and concerned with operations directly against the enemy, and a base section concerned with

[1] A.M. File S.62612.

reinforcements, long range bombing, etc.; both sections would need meteorological information, whilst Army Field H.Q. and sub-formations, which might be separated from the R.A.F., would also need meteorological services. A number of new airfields in Northern Ireland for immediate use in Coastal Command operations over the Atlantic but also for use for defence purposes in the event of invasion, were also being planned.

To meet these requirements, a scheme was prepared by the Chief Meteorological Officer which envisaged the formation at H.Q., R.A.F.N.I. of a Main Forecasting Centre which would supply meteorological information needed by the A.O.C. and operational staff, while additional meteorological personnel would be posted for employment at the new airfields. The Army Meteorological Liaison Officer, who was transferred from Belfast to the newly formed H.Q. British Troops in N. Ireland (B.T.N.I.), Lisburn, was to be given a small permanent staff, to assist in distributing information to the Army. In the event of field operations, the meteorological centre at H.Q., R.A.F.N.I. would be reduced and staff withdrawn from the new airfields in order that a Main Mobile meteorological unit and three small Army meteorological units could be formed; the Main Mobile Unit would accompany Advanced R.A.F., H.Q. and would supply the basic data and forecasts required in the field, while the Army units, one with H.Q. Field Force and one each with the two Divisional H.Q.s, would interpret and disseminate the information required within their sphere. The scheme detailed the equipment, communications and staff which would be required for the proposed organisation. The scheme was adopted in the main, but was expanded in July 1940 to include small mobile detachments, when required, with Wing Servicing Units. The scheme as finally agreed included an establishment of 12 officers and 32 airmen together with M/T drivers and a dispatch rider. Transport for the Main Mobile meteorological unit was to consist of a 5-ton lorry, a 30-cwt. van for provisioning, a staff car for the Chief Meteorological Officer and a motor cycle.

The scheme remained the basis for the meteorological organisation in Northern Ireland for the next eighteen months. The meteorological section in Northern Ireland worked as a single organisation covering all branches of the Services and was extended as necessary for such special operations as the Belfast smoke screen, the Belfast and Londonderry Balloon Barrages, etc. The Chief Meteorological Officer co-ordinated the work of the section as a whole, organised telegraphic and auxiliary reporting stations and effected liaison with all bodies interested in the meteorological service in Northern Ireland.

Liaison with Eire Meteorological Service[1]

At first, the Chief Meteorological Officer was charged with the task of establishing contact with the Director of the Eire Meteorological Service, but the policy was then changed and a questionnaire was sent to the Eire Meteorological Service asking for information regarding their resources and plans in the event of invasion by the Germans. A reply was received, but joint meteorological operations were not planned.

In accordance with pre-war arrangements, the observations made in Eire were collected in Dublin and sent to ETA, at first by G.P.O. telegram but later by teleprinter. The reports from Malin Head and Blacksod were also sent direct to Aldergrove by telegram.

[1] A.M. File S.5707.

Policy Changes in relation to No. 15 Group

The Meteorological Office decided in November 1941 to place the responsibility for meteorological offices at the Coastal Command Stations in Northern Ireland on the Senior Meteorological Officer at H.Q. No. 15 Group, Liverpool. This resulted in a dual responsibility for meteorological administration within Northern Ireland which, although it had certain disadvantages from the viewpoint of the Chief Meteorological Officer, Northern Ireland, was advantageous to the Senior Meteorological Officer, No. 15 Group, who was responsible for meeting meteorological requirements for No. 15 Group operations.[1]

The Senior Meteorological Officer, No. 15 Group, also made representations regarding the communications system and asked for teleprinter lines to be installed from the switchboard at the Type 1 office in Liverpool direct to the meteorological offices at Coastal Command stations in N. Ireland. At first, the limited number of channels available in the submarine cables made this impracticable and the Main Forecasting Centre at H.Q., R.A.F.N.I. remained the focal point of the meteorological teleprinter network in N. Ireland. Later all observations sent to ETA were automatically reported to No. 15 Group and in 1944, lines from Coastal Command meteorological offices in N. Ireland were routed direct to the Type 1 office at H.Q. No. 15 Group.

The number and location of meteorological offices under the control of the Meteorological Section, H.Q., R.A.F.N.I., varied from February 1942 as operational squadrons were transferred, each meteorological office reverting to R.A.F.N.I. control when the station ceased to be used for operations by No. 15 Group.

The arrangements for the provision of mobile meteorological units in Ireland were based on a unified meteorological set-up capable of rapid redistribution; the staff for the mobile units were to be reduced as a result of the threat of invasion. In view, therefore, of the transfer of control to No. 15 Group of the meteorological offices at the Coastal Command airfields in Northern Ireland a new organisation was prepared which provided for a larger establishment of staff at H.Q., R.A.F.N.I. and for the various Army units.[2] In fact, the new organisation was never fully implemented and as a result of the steadily decreasing threat of invasion, the provision of mobile units became less and less important. Finally, in August 1943, the transport and equipment held by the Meteorological Section primarily for this purpose was surrendered to the transport pool, and all attempts to maintain mobility were abandoned. In June 1943, the post of Chief Meteorological Officer, Northern Ireland was changed to that of Senior Meteorological Officer.

Early in 1942, H.Q. 82 Group (Fighter Command) was formed at Stormont, Belfast, and was supplied with meteorological information by a specially provided teleprinter. As the meteorological requirements of 82 Group Operations Room steadily increased, it was decided to transfer the Main Forecasting Centre to Stormont, where, although remaining an integral part of the R.A.F.N.I. organisation, it could more conveniently carry out the major day-to-day duties of supplying information to No. 82 Group. In October, 1942, H.Q., R.A.F.N.I. was itself transferred to Stormont and absorbed H.Q. No. 82 Group. The Meteorological Section, R.A.F.N.I. was thus once again situated with its parent formation.

[1] M.O.O. 2039. [2] A.M. File S.62612.

A number of airfields were in process of being handed over to the U.S.A.A.F. in 1942, while new airfields were being constructed. The first airfield to be handed over was Eglington, in July 1942, followed by Longkesh, Ballyhalbert and St. Angelo. New airfields for U.S. Forces were constructed at Maydown (near Londonderry) and Langford Lodge (near Aldergrove). The meteorological offices at each of these airfields were connected to the meteorological teleprinter switchboard at H.Q., R.A.F.N.I. and thus to ETA. At Nutts Corner an airfield was being developed as a Transatlantic terminal.

The U.S. Weather Offices were gradually closed during 1944 and 1945 and the final change in organisation before the end of the war was the transfer to Aldergrove in February 1945 of the Main Forecasting Centre together with the meteorological teleprinter switchboards.

Communications

The main system for collecting and distributing meteorological data in Northern Ireland was a teleprinter network which was periodically modified to meet the needs of the moment. The only teleprinter link with the Central Forecasting Office (ETA) was a line from Aldergrove until September 1940 when the Main Forecasting Centre was also connected to ETA, and became the focal point of the many lines later installed in Northern Ireland after the installation of a switchboard in July 1941. In 1942, the needs of the Type 1 office at H.Q. No. 15 Group were met by the provision of a line from the Main Forecasting Centre on which collective messages for Northern Ireland were repeated to No. 15 Group while being sent to ETA. In 1944 direct teleprinter communications between the Type 1 at H.Q. No. 15 Group and offices under its control in Northern Ireland was established, these offices being removed from the meteorological switchboard at H.Q., R.A.F.N.I.

When the Main Forecasting Centre was formed, it was foreseen that stations might become operational before teleprinter lines could be installed while, in the event of field operations calling for the assembling of the Mobile meteorological units, communications would certainly be very limited and would be mainly by W/T or telephone. A scheme was, therefore, devised whereby information could be passed by telephone, with due security precautions, suitable for providing a secondary meteorological office with advice for forecasting. The idea was to provide a comprehensive forecast, to be known as the ' Master Forecast ', for Northern Ireland, in which were included all the details required by the various specialised meteorological units, *e.g.* chemical warfare data, wind for artillery Meteor reports and for aviation, etc. In addition, two ' pictorial weather charts, one of actual and one of forecast conditions, were to be described by a system of co-ordination, similarly scrambled for transmission by telephone. Although the scheme was not required for use in the field it was used on almost every occasion when a new station was opened and proved an alternative to a full teleprinter service.

Although the provision of a meteorological W/T unit to accompany a Mobile Meteorological Unit was originally contemplated the equipment and staff were never forthcoming, but W/T services provided by the R.A.F. were sometimes used, mainly to receive the ETA emergency transmissions after the air raids on Belfast had caused the temporary dislocation of the teleprinter service.

Services

R.A.F.N.I. : From July 1940, forecasts, reports and other information were supplied to the Operations Room R.A.F.N.I. Forecasts were also issued to all R.A.F.N.I. squadrons, either by the station meteorological office or direct from the Main Forecasting Centre. Until 1942, R.A.F.N.I. requirements were based on anti-invasion preparations, and operations consisted of practice mobility exercises—for which a Mobile Meteorological Unit was provided—and a patrol of the Ulster coasts, forecasts for which were issued continually. After H.Q.R.A.F. N.I. and No. 82 Group were fused in October 1942, the main interest of the operations staff was the air defence of Northern Ireland and meteorological information supplied was for normal fighter operations.

Coastal Command : All meteorological services for the operational squadron of No. 15 Group were under the direction of the Senior Meteorological Officer, No. 15 Group. Staff and equipment for the stations concerned were provided from R.A.F.N.I. Establishments. Full meteorological services were provided for the O.T.U.s of No. 17 Group which were attached from time to time to R.A.F.N.I. airfields ; the flights were similar to those of operational squadrons and required similar meteorological information.

Army : Army requirements consisted mainly of forecasts relating to chemical warfare and artillery Meteor reports and were largely met by the meteorological unit at H.Q. B.T.N.I. In the case of routine Meteor reports for A.A. guns and for the coastal batteries, the nearest convenient R.A.F meteorological office provided the required information ; thus avoiding the risk of the service being interrupted should communications fail. A series of special forecasts of the weather in Southern Eire, N.W. France and western English Channel were supplied during the ' invasion ' period of 1942 and 1943. Special mobile pilot-balloon parties were sent to Army field exercises and practice shoots. Wind measurements were made and Meteor reports prepared in the field, while forecasts were obtained from the mobile party from the most convenient meteorological office. As many as twenty field exercises were catered for in this way in one month of 1942.

The Navy : Forecasts for the Navy were supplied by the Main Forecasting Centre to the Naval Base, Londonderry, from 1940 to 1943. They covered the weather of the Ulster coasts and western approaches and were issued both as a routine and on request. From 1941, similar forecasts were supplied to detachments of the R.N.A.S. stationed from time to time at Sydenham and Eglington. A naval meteorological office was opened at Sydenham in November 1943 and assumed the responsibility for meeting naval requirements.

Fighter Command : A full meteorological service was provided for the Fighter Control Operations Room at H.Q. No. 82 Group which was opened early in 1942. The Chief Meteorological Officer, R.A.F.N.I. visited the meteorological offices at H.Q. Fighter Command and H.Q. No. 11 Group, Uxbridge, to study the meteorological aspects of Fighter requirements, and the procedure developed on the mainland was copied as far as possible.

U.S.A.A.F. : U.S. Forces arrived in N. Ireland in January 1942, and preparations were then made for the arrival of U.S.A.A.F. squadrons, the first of which took over the airfield in Eglington in July 1942. Their meteorological needs were met by the existing R.A.F.N.I. meteorological office at that station. Other airfields were taken over or built for the U.S.A.A.F. during 1942, 1943 and 1944, and eventually six U.S. Weather offices were operating in Northern Ireland. Each of the offices was connected to the R.A.F.N.I. teleprinter system and a full service of meteorological data was provided. For a time several meteorological officers were staffed jointly by British and American personnel. Detachments of the U.S.A.A.F. Weather Service (N.C.O.s) were attached to the Main Forecasting Centre and other R.A.F.N.I. meteorological offices for training in procedure and practice of the Meteorological Office before proceeding to their own stations. It was agreed in April 1943 that the Main Forecasting Centre should be manned jointly by British and American staff in the ratio of 3 R.A.F. to 2 U.S. personnel; this policy was implemented immediately. The U.S. Forces in Northern Ireland began to withdraw towards the end of 1944, few remaining by V.E. day.

Other Services : A meteorological service was provided for the Balloon Barrage Squadrons at Belfast, Londonderry and the water-borne detachment in Belfast Lough. Forecasts were supplied by the Main Forecasting Centre while an observing office was established at Londonderry to watch the local conditions and to pass forecasts and warnings to the local Balloon Barrage H.Q. The Main Forecasting Centre also met the needs of the Belfast Smoke Screen, formed in April 1941. Meteorological services were provided at Sydenham airfield for civil aviation, No. 24 (Communications Squadron) and No. 8 Ferry Pool.

Special arrangements were made during a Ministry of Home Security lighting experiment, held at Ballymoney from December 1940 to February 1941, the aim of which was to ascertain the maximum of lighting for a railway goods yard compatible with the risk of its being observed from the air at a distance. A meteorological observer was provided to record visibility, humidity, etc. and forecasts were given to the observing aircraft.

An ' Aviation Met. Report of Northern Ireland ' was prepared in April 1942, and was subsequently published as M.O.M. 365/16.

Location and Function of Units

A Chief Meteorological Officer was appointed to H.Q. R.A.F.N.I. Belfast, in July 1940 and after various moves was transferred to Aldergrove in February 1945. He was responsible for advising the A.O.C. and senior members of the other Services and for the administration and control of the R.A.F.N.I. Meteorological Section.

The Main Forecasting Centre was formed at Aldergrove and transferred to Holywood in July 1940. After moving to Belfast Castle in November 1940 and to Stormont in March 1942, it was finally transferred to Aldergrove in February 1945. It was the parent forecasting unit for all R.A.F.N.I. meteorological offices.

After an Army Meteorological Liaison Officer was appointed to Northern Ireland Division, Belfast, in January 1940, an Army Meteorological unit was

formed at H.Q. B.T.I. in August 1940. It was responsible for arranging meteorological services to all Army formations including the supply of information to H.Q. B.T.I. and Divisional H.Q.s. It was closed in May 1943.

A Type 2 meteorological office had been formed at Aldergrove before the war. It came under the control of the Type 1 office at No. 15 Group in February 1942 but reverted to R.A.F.N.I. control in September 1943. It met all local meteorological requirements.

A Type 4 meteorological office had been formed at Sydenham before the war and was maintained there until March 1944. It dealt with local meteorological requirements under the guidance of the Main Forecasting Centre.

A Type 4 meteorological office was opened at Londonderry in November 1944 to make local observations and for passing forecasts and warnings to H.Q. Londonderry Balloon Barrage. It was transferred to Eglington in March 1942 and taken over by the Naval Meteorological Service in June 1943.

A Type 4 meteorological office was opened at Limavady in December 1940, and was upgraded to Type 3 in January, and to Type 2 in April 1941. It was controlled by the Type 1 office at H.Q. No. 15 Group from February 1942 to April 1942 when it reverted to R.A.F.N.I. It was transferred to the U.S. Weather Service in January 1944. This office met local aviation requirements, mainly for Nos. 15 and 17 Groups.

A Type 2 office was formed at Lough Erne (Castle Archdale) in March 1941 and was transferred to No. 15 Group in February 1942. It met the needs of the Flying Boat base at Lough Erne.

A Type 4 office was formed in December 1941 at Ballyhalbert and operated until the end of the war. It supplied information to Fighter Squadrons at Ballyhalbert and Kirkistown (satellite).

A Type 4 office was opened at Nutts Corner in November 1942 and after a temporary closure from August 1942 to June 1943, was taken over by U.S.A.A.F. Weather Service in October 1943. Initially, this office obtained forecasts for Coastal Command Squadrons but later it functioned for Transport Command.

A Type 4 office was opened at St. Angelo in June 1942 and throughout the war supplied meteorological information to Fighter Squadrons based on the station.

A Type 3 office was opened in July 1943 at Bishop Court and operated during the remainder of the war. It provided forecasts and meteorological instruction to the local units of Flying Training Command.

A Type 4 office operated at Longkesh from January 1943 to February 1944 to obtain forecasts for local units of Nos. 17 and 44 Groups.

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CHAPTER 11

FERRY COMMAND AND TRANSPORT COMMAND

Overseas Air Movement Control Unit, Gloucester

An organisation was needed from the summer of 1940 to provide flying control for the following non-operational flights into and out of the United Kingdom from and to destinations overseas :—

(*a*) Transatlantic delivery flights of aircraft bought for the R.A.F. in U.S.A. and Canada, arrangements for which were made by a civilian ferrying organisation (ATFERO) working under M.A.P.

(*b*) Flights of reinforcing or replacement aircraft to all units of the R.A.F. outside the control of the Home Commands.

(*c*) The R.A.F. (air mail) service via Malta to Egypt.

(*d*) Transatlantic and other long distance flights by civil aircraft.

Flights in some of these categories had already started and were becoming more frequent. It was strongly felt that aircraft in category (*a*) must be provided with an efficient meteorological and signals service so that they would not suffer interference on entering the operational zones around the British Isles, and that all necessary meteorological data and advice must be made available to whatever control organisation might be established.

It was decided in July 1940 to set up a small operational H.Q. at Gloucester especially to deal with transatlantic delivery flights[1] but this decision was superseded in August 1940 by one to form a central unit at Gloucester, under Maintenance Command, to undertake the control of all four categories of flight specified in the previous paragraph. This new unit was to :—

(*a*) Organise the best possible signals and meteorological facilities for flights in all four categories.

(*b*) Issue instructions on signals procedure and meteorological organisation.

(*c*) Control the movements of all non-operational air traffic, military and civil, into and out of the British Isles, from and to stations outside the control of the Home Commands.

(*d*) Co-operate with Air Ministry in arranging delivery routes.

The necessary meteorological organisation already existed to a certain extent but it had to be linked up with the new control unit and provision made for its development in certain directions. The new control unit would need a 24-hour forecaster who would be available to visit the departure air fields of outward flights to brief aircrews on the forecasts issued to them.

This Overseas Air Movement Control Unit (O.A.M.C.U.) was formed at Gloucester on 9 September 1940 and a meteorological office was set up on 14 September. The immediate commitment was to provide meteorological facilities for the delivery by air of 50 Hudson III aircraft from Botwood (Newfoundland) to Aldergrove. For this, co-operation with the Canadian

[1] A.M. File S.64937/I.

Meteorological Service's office at Botwood was essential, and it was decided to operate a meteorological organisation similar to that which had been introduced in 1937 for civil experimental flights between Newfoundland and Eire, and developed in the following years. This would consist of a routine exchange of synoptic data and analyses for the construction of Atlantic charts, and the transmission from Gloucester to Botwood of a forecast for the second half of the route Botwood—Aldergrove with landing forecasts for Aldergrove and alternative airfields, on each occasion of intended flights. The meteorological office at Botwood would then supply a flight forecast to the Captain of each aircraft before departure, and this forecast would be repeated to Gloucester by W/T in a code and cypher. During flight, any necessary amendments to this forecast would be issued to aircraft in code and cypher by Botwood while the aircraft was under Botwood control and by Gloucester after it had been transferred to O.A.M.C.U. control. The first formation, six Hudson aircraft, flew from Newfoundland to Aldergrove in November 1940 and an examination of the working of the organisation on that occasion showed the need to supplement the scanty meteorological data available for the Atlantic by reports made by aircrews immediately on landing, regarding the weather conditions experienced during flight; in due course this became routine procedure. Gloucester's assumption of its full responsibilities in regard to other non-operational flights was meanwhile being arranged, and close personal liaison was maintained between the Controllers and Meteorological Officers at O.A.M.C. During December 1940, O.A.M.C.U. began to assume control of delivery flights from the United Kingdom to the Middle East which normally left from Thorney Island, and the mobile forecaster at Gloucester travelled to the departure airfield to give the crews meteorological briefing before departure.

Meanwhile, the possibility of using Bermuda as a staging post for the delivery by air to the United Kingdom of Catalina flying boats was being examined and, in January 1941, the Meteorological Office Liaison Officer with the United Kingdom Air Liaison Mission in Canada visited Bermuda to discuss the necessary meteorological arrangements with the Bermuda Government meteorologist. As a result, it was decided to post to Bermuda a Meteorological Office forecaster to assist the Bermuda Meteorological Service in providing the necessary facilities for the delivery flight. It was also arranged for the exchange of data between Gloucester and Botwood to be extended to include Bermuda and for a meteorological organisation similar to that for the land-plane deliveries from Botwood to the United Kingdom, to be operated for the flying boat deliveries through Bermuda. The United Kingdom terminal for these deliveries would be Greenock at first, and the flights would be controlled by O.A.M.C.U.

The meteorological work at O.A.M.C.U. increased steadily in the early months of 1941 in regard to delivery flights across the Atlantic and from the United Kingdom to the Middle East via Gibraltar. The latter were then leaving from St. Eval or Portreath in the case of land-planes and from Mount Batten in the case of flying boats. Gloucester also issued all forecasts for transatlantic and other long-distance flights by civil aircraft between the United Kingdom and Lisbon, and between the United Kingdom and Shannon. Additional forecasters were posted to O.A.M.C.U. at intervals.

At about that time, it was decided to replace Aldergrove by Prestwick as the main United Kingdom terminus for all transatlantic delivery flights of land-planes, and a meteorological office was set up at Prestwick where the

officer in charge would issue landing forecasts and reports to incoming aircraft and interview pilots on arrival to obtain information about the conditions experienced during flight.

The problem then arose of returning to Canada, for further delivery flights, the crews who had flown from there to the United Kingdom. B.O.A.C. was given the task of transporting them and the first flight left from Squires Gate in Lancashire in April 1941. O.A.M.C.U. provided the meteorological facilities for this flight and a forecaster and an assistant were detached from Gloucester to Squires Gate to give satisfactory service to the Captain of the aircraft before he left.[1] The flight forecast was prepared at Gloucester and telephoned to Squires Gate where it was converted into standard written form for the Captain and issued to him by the forecaster with the necessary exposition of its significant features. Further flights were made from Squires Gate to Newfoundland in May and June.

The Air Ministry had meanwhile decided to replace Squires Gate by Prestwick as the United Kingdom departure base for westbound transatlantic flights. In regard to the related problem of transferring the control organisation for all Atlantic flights from Gloucester to Prestwick, it was decided to set up a separate control centre at Prestwick, leaving O.A.M.C.U. to continue to deal with southbound flights. A main meteorological centre had, therefore, to be set up at Prestwick to serve the control organisation to be set up there and to provide all the meteorological facilities needed for incoming and outgoing transatlantic flights, including the personal briefing of outgoing crews. It was also to provide advice for ferry flights from Prestwick to various parts of the United Kingdom.

Formation of Ferry Command

Ferry Command was formed at Dorval (Montreal) on 20 July 1941 to organise and control the delivery of aircraft by air across the Atlantic and to take over the functions of ATFERO, and, on 15 August, No. 44 (Ferry) Group was formed at Gloucester in Ferry Command.[2] O.A.M.C.U. was absorbed by No. 44 Group and disbanded. No 44 Group became directly responsible to Ferry Command for all matters affecting transatlantic flights and to Air Ministry for all matters regarding air movements to and from the United Kingdom, Middle East, Malta, Gibraltar and other overseas destinations; it also took over R.A.F. station, Prestwick. Later in the year, the Meteorological Office Liaison Officer to the United Kingdom Air Mission in Canada was appointed as Meteorological Officer to Ferry Command at Montreal to act as meteorological adviser to the A.O.C.-in-C.

While these changes in organisation and administration were taking place advances were being made in the technical aspects of meeting the meteorological needs of controllers and aircrews. Arrangements were made for maintaining during flight a meteorological log in a standard form, which provided for the recording of such details as the weather, temperature, cloud, wind and ice formation on the aircraft. This log was handed to the meteorological officer at the arrival airfield as soon as the aircraft landed, and the information it contained was converted into code and distributed by teleprinter to all forecasting centres concerned. These reports were called FERAT reports. Similar

[1] A.M. File S.64937/I.

[2] A.M. File S.64860.

arrangements already existed for aircraft reports to be made by operational aircraft of Coastal Command, the forecasters at Gloucester being very dependent on this type of information. Every effort was made to secure such reports in maximum quantity and with the greatest possible speed.

During the early part of 1941, two ships based at Halifax, Nova Scotia, and specially equipped for taking routine meteorological observations and signalling them to shore, in cypher, were stationed by turns in the western North Atlantic several hundred miles east of Newfoundland. Their reports were a vital contribution to the forecasting work in the United Kingdon and Canada for Atlantic flying and the loss of the ships by enemy action was a heavy blow to the transatlantic forecasting organisation, particularly as it occurred at a time when Atlantic flights in both directions were rapidly increasing in numbers and frequency. However, the development at about this time of daily meteorological reconnaissance flights over the Atlantic to cover distances of 500 miles from bases in northern Ireland and southwest England did much to improve the information available to forecasters. Similar reconnaissance flights based on Iceland, Canada and the Azores were later begun.

There was a significant development in the supply of data and advice to Captains of westbound transatlantic aircraft at this stage. The written flight forecast was now supplemented by a pictorial representation of the forecast in the form of a vertical cross section along the route, showing the cloud distribution (vertically and horizontally), ice formation and weather, all in symbolic form, together with a line showing the freezing level.[1] This form of presentation proved very popular with forecasters and pilots, particularly in connection with pre-flight briefings, and quickly become established as standard procedure.

A Type 1 office was set up at Prestwick in October 1941 to meet the increasing meteorological needs. The new office, which was located with the new control centre, absorbed the small organisation which had hitherto been provided. A nucleus of forecasters was transferred from Gloucester and others were posted from elsewhere as the work increased. Reception of the W/T synoptic broadcast transmissions from Arlington, U.S.A., was begun, and point-to-point exchanges of data, analyses and forecasts with Botwood were established. Analyses were also transmitted to Bermuda and Iceland.

As the result of a request by transatlantic ferry pilots for hourly weather reports to terminal airfields to be transmitted to incoming aircraft, transmissions began on 1 November 1941 from Prestwick in respect of eastbound aircraft and from Botwood for westbound aircraft.

Meteorological Activities at H.Q. No. 44 Group, Gloucester

It had been thought that the transfer to Prestwick of the transatlantic work would allow the Gloucester meteorological office to concentrate almost exclusively on the non-Atlantic flights for which it was responsible, but it became clear that as H.Q. No. 44 Group was responsible for authorising flights, the meteorological office must be able to advise the R.A.F. senior staff at Group H.Q. in regard to the Atlantic as well as Mediterranean conditions. Moreover, Gloucester had to be prepared to assume Prestwick's responsibilities in the event of that station being put out of action by enemy or other causes. It was decided,

[1] A.M. File S.64937/II.

therefore, to maintain at Gloucester a skeleton Atlantic organisation which could be quickly brought into full operation if needed. Such an eventuality never, in fact, arose.

It was decided at first to establish two mobile R.A.F. units at No. 44 Group to dispatch aircraft from different stations to the Mediterranean, but it was later decided to concentrate most of the dispatching at Portreath, where a meteorological office was accordingly set up. In addition, a routine service to Egypt by Liberator aircraft was established at Lyneham, which was served by a mobile forecaster from Gloucester until a Type 2 meteorological office was opened at Lyneham in October 1942. Other airfields than Portreath and Lyneham were, however, used fairly often for departures of southbound aircraft. Departures for Gibraltar took place from Trebaluze, where a forecasting office was opened in February 1942, but the station was closed in June as the airfield proved unsuitable. Aircraft left for Malta from Stanton Harcourt and Harwell and from Hurn for the Middle East. Such commitments made heavy demands during most of 1942 on the forecasters at Gloucester, who had constantly to go to various airfields for the sole purpose of personally briefing the departing aircrews.

Although Whitchurch (Bristol) was a civil airfield, and thus not a station of No. 44 Group, the Senior Meteorological Officer at Gloucester supervised its meteorological office. Besides meeting the needs of the Ferry Pool which ferried aircraft within the United Kingdom, it supplied the forecasting service for K.L.M. aircraft operating a regular service from Whitchurch to Lisbon. Similarly, the meteorological office at Poole, guided by Gloucester, supplied the forecasting service for B.O.A.C. flying boats which were maintaining a regular service to Lisbon via Shannon.

Meteorological offices were specially opened or temporarily reinforced at Hurn, Exeter, Predannack, Portreath, St. Eval and Chivenor in November 1942 to provide the forecasting service for the dispatch of a large number of aircraft to Gibraltar in connection with the North African landings. Gloucester prepared the forecasts and passed them to the appropriate stations for issue and briefing of crews. Soon after the North African landings, special dispatches of aircraft to Blida (Algiers) were made from these stations. Most of the special facilities provided in connection with these operations were withdrawn during December.

Reinforcement flights from America to North Africa via Bermuda and Gibraltar were organised soon after the North African landings, and forecasts for the section of the route 30° W. to Gibraltar were prepared at Gloucester and sent to Bermuda. In order to give the Gloucester forecasters the benefit of the opinions of the Gibraltar forecasters, routine advisory forecasts for the section 20° W. to Gibraltar were prepared at Gibraltar and sent to Gloucester for information.

Intensification of Transatlantic Flying

During 1942, transatlantic flying activity increased rapidly both in regard to the number of aircraft delivered to the United Kingdom and to the number of westbound flights carrying returning crews. This was due partly to the development of alternative routes and airfields. It was decided that a limited number of westbound flights should leave from Nutts Corner, Northern Ireland, instead of Prestwick. In order to brief the Captains personally and to supply the

charts and forecasts for these departures, the Meteorological Officer-in-charge at Aldergrove, the nearest meteorological office to Nutts Corner, visited Prestwick in February to become familiar with the transatlantic organisation and to discuss liaison between Prestwick and Aldergrove. Prestwick was to prepare the flight forecast and telephone it to Aldergrove, where a forecaster would prepare the necessary documents and take them to Nutts Corner for briefing. The Senior Meteorological Officer, No. 15 Group, at Liverpool, administered the meteorological office at Aldergrove. As No. 15 Group was one of the Coastal Command Groups responsible for operational flying over the Atlantic from United Kingdom bases, its Senior Meteorological Officer had many problems in common with his opposite number at Prestwick, and the fullest co-operation and exchange of information between them was necessary, apart from the particular question of activities at Nutts Corner. A speedy exchange of all weather reports supplied by aircraft was especially important. The fact that the same Branch of the Meteorological Office administered the two meteorological offices in question ensured effective liaison.

Delivery flights from Canada on a northeastern route, *i.e.* via Labrador, Greenland and Iceland, began in the spring of 1942. The Canadian Meteorological Service set up a meteorological office in Labrador at the Goose Bay airfield which became a staging post for aircraft flying direct to the United Kingdom via the northern route or via the direct route when weather conditions in Newfoundland were unfavourable. The meteorological arrangements at the Greenland airfields were the responsibility of the United States authorities whose representatives visited the Meteorological Office and Prestwick in April 1942 to discuss the organisation. In the same month, the main transatlantic forecast office on the Candian side, which had until then been maintained in Newfoundland, was transferred to Dorval and set up alongside H.Q. R.A.F. Ferry Command. Simultaneously, the Meteorological Officer-in-charge in Newfoundland was transferred to Dorval and acted as meteorological adviser to the A.O.C.-in-C., Ferry Command; the meteorological office at Newfoundland then came under the control of the Senior Meteorological Officer at Dorval who later played an important part in developing the meteorological organisation of the North Atlantic routes and collaborated closely with the staff of Ferry Command H.Q.

The question arose late in 1942, of setting up at Prestwick a U.S.A.A.F. meteorological unit to help the U.S.A.A.F. Operations Officer who already had charge there of arrangements relating to transatlantic flights of U.S. delivery aircraft. It was decided to attach a U.S.A.A.F. Weather Officer to the Prestwick meteorological office. Early in 1943, it was decided to set up a Joint U.S.A.A.F.–R.A.F.F.F. (R.A.F. Ferry Command) Operation Unit at Prestwick to control the ever increasing flow of American and British aircraft across the Atlantic and, as a result, a U.S.A.A.F. meteorological unit was set up at Prestwick in April 1943.[1]

During December 1942, B.O.A.C. ferry aircraft began to transmit to Dorval and Prestwick coded and cyphered reports of the meteorological conditions being met during transatlantic flights. These reports (Ferimet) were usually made at hourly intervals and formed a valuable addition to the scanty information available from the North Atlantic.

[1] A.M. File S.69291.

A scheme was approved in 1942 for exchanging forecasters periodically between Prestwick and Montreal in order to—

(*a*) Give the forecasters clearer insight into forecasting problems for the half of the North Atlantic with which they were less familiar.

(*b*) Give them actual experience of local meteorological conditions at terminals on the other side of the Atlantic.

(*c*) Assist in securing uniformity of procedure in regard to providing meteorological information for transatlantic flying.

The first Canadian forecaster did not, however, arrive at Prestwick until March 1943, and the first British ' exchange ' forecaster did not leave Prestwick for Montreal until May 1943.

It was arranged in March 1943 to provide forecasts for flights on the direct route Greenland to the United Kingdom. Forecasts for the second half of the route, with landing forecasts for Prestwick and Stornoway were transmitted daily from March 11 by Prestwick to the U.S.A.A.F. Meteorological H.Q. in Greenland for use in briefing Captains.

Flights to Moscow

B.O.A.C. Liberator aircraft began a series of flights between Prestwick and Moscow in October 1942, the meteorological organisation being similar to that for transatlantic flights. The first flight, an experimental one, carried a party of civil aviation officials, and included the Head of M.O.7 as a meteorological member. In Moscow, the party discussed arrangements for future flights with their Russian counterparts. Later flights in the series were made at intervals during the winter of 1942–43.

Flights between Prestwick and Marrakesh began early in 1943 and, for southbound flights, Gloucester supplied Prestwick with a route forecast for 52° N. to 34° N. on this route, and with landing forecasts for the terminal and suitable alternate airfields. Prestwick then made, and issued to the aircraft Captain, a complete forecast for each route.

Plans were made during January and February 1943 to supply forecasts for delivery flights of aircraft by Russian crews from Errol (East Scotland) to Moscow. A forecaster was, therefore, attached temporarily to Errol from Prestwick and a meteorological organisation similar to that used for transatlantic flights was operated. Moscow sent Prestwick coded forecasts for the second half of the route and for Russian terminals, and Prestwick then prepared forecasts for the whole route and telephoned them in code to Errol where a Russian speaking assistant entered them on suitable forecast forms. Flights took place from February until May.

Formation and Expansion of Transport Command

Transport Command was formed on 25 March 1943 and took over the functions of Ferry Command. It at first comprised Nos. 44, 45 and 216 Groups, whose headquarters were at Gloucester, Dorval and Cairo respectively. No. 45 Group was, in effect, the re-establishment of Ferry Command as a Group at Dorval. A meteorological section began to form at Transport Command H.Q. soon after it moved to Harros in April 1943. Its primary function was to supply complete and up-to-date information on meteorological conditions obtaining in the North and South Atlantic and on the reinforcement routes to North and

West Africa and the Middle East in order to enable the flow of U.S. and British aircraft to be regulated into and out of the United Kingdom. This necessitated a 24-hour forecasting service embracing areas covered by Transport Command activities as well as the routes operated by B.O.A.C. Meteorological information relating to flights of 'Very Important Persons' from the United Kingdom was also needed. A Senior Meteorological Officer was appointed to the Command in May 1943.

The formation of Transport Command did not alter the functions of No. 44 Group whose meteorological needs continued to be met as previously, the main meteorological offices being at Prestwick and Gloucester. Meteorological facilities were also needed in all oversea areas through which Transport Command operated. These were generally provided by expanding or reinforcing the meteorological services which already existed to meet the needs of the R.A.F. operational units in the area. Thus, the needs of No. 216 Group were met by the meteorological service of Mediterranean and Middle East Command, and the local R.A.F. meteorological services met requirements in Bermuda, Iceland and West Africa. The Canadian Meteorological Service continued to meet requirements at Dorval. In the U.S.A. and South America, meteorological facilities were provided by the U.S. military meteorological service which also set up several offices of its own to meet the needs of U.S. Transport Command, *i.e.* at Prestwick, Bermuda, Iceland and North Africa, and later at Gloucester and St. Mawgan.

The initial charting needs were the preparation of synoptic charts covering all military and civil oversea, ferry, delivery and reinforcement routes; the main routes were North and South Transatlantic, North-east Ferry route; and United Kingdom to Nassau, North West Africa and Middle East to India. An attempt was made to plot all the relevant synoptic data but this effort proved unjustifiable as there were very few enquiries regarding the weather over the more distant sections of the routes. After August 1944, the charting routine was confined to areas covering those sections of the routes emanating from the United Kingdom. Besides being provided with two teleprinter channels to ETA, the meteorological office at H.Q. Transport Command was linked to the Prestwick-Gloucester meteorological teleprinter circuit, but it did not receive direct by W/T the synoptic data broadcast by forecasting centres overseas. All such W/T transmissions were received at ETA and passed to H.Q. Transport Command on the second teleprinter channel; to make time for this, much of the data normally included in the second channel broadcast from ETA had to be omitted from the transmissions to Transport Command. In fact, it was some time before the full meteorological teleprinter facilities referred to above could be provided and at first the R.A.F. operational teleprinter channels to Gloucester and Prestwick were used to obtain routine synoptic data for North Africa and North America respectively.

An important part of the work of the Transport Command meteorological office was to supply climatological data covering the areas across which the Command's routes extended. A considerable amount of climatological data was accumulated in order to meet the request for climatological data and reports, but reference often had to be made to the Investigations Branch of the Meteorological Office for the information required. Much of the climatological data was required for insertion in the Transport Command Air Route Books, prepared by the Navigation Branch, which included statements of the

weather in all Transport Command Staging Posts on the routes and weather along the routes themselves. Towards the end of 1944, much climatological information was supplied for the United Kingdom—India route. In March 1944, data were supplied for a proposed new Transport Command route from Ceylon to Australia.

Many enquiries received at the meteorological office at H.Q. Transport Command related to weather on the United Kingdom–Gibraltar route. As Gloucester did the forecasting for this route, the views of the duty forecasters at the two meteorological offices had to be co-ordinated, and, in November 1943, a routine daily telephone discussion was introduced between the meteorological offices at Gloucester and H.Q. Transport Command. This daily telephone conference was later extended to include a number of meteorological offices in Transport Command.

The functions of Transport Command were restated in December 1943, and the formations wholly or partly under the Command's control throughout the world were officially listed. Besides the formations already mentioned, there was a Wing (No. 114) in West and Central Africa and a Group (No. 229) in South-east Asia Air Command. The memorandum giving this information foreshadowed the formation of a new transport wing for the control of certain air transport services in the United Kingdom and on the United Kingdom–India trunk route, and a new transport group in the Allied Expeditionary Air Force; these formations, No. 116 Wing and No. 46 Group, became operational in the early part of 1944.[1]

The headquarters of No. 46 Group, which was to undertake air transport operations in support of the landings in Normandy, were set up in March 1944 at Harrow Weald. At first, meteorological needs were met by H.Q. Transport Command which was about two miles from Group H.Q., and information was passed by telephone and dispatch rider. It was arranged in April 1944 for a forecaster to visit No. 46 Group H.Q. daily at routine times and if necessary, to discuss with Air Staff the meteorological conditions in relation to No. 46 Group operations, but in May 1944 a meteorological office was set up at the Group H.Q.[2] A Senior Meteorological Officer was appointed in June 1944 and by the end of the month, the office had taken over most of the forecasting needs of that H.Q. from the meteorological office at Group H.Q. Close liaison with the meteorological office at H.Q. No. 38 Group, which was necessary as the functions of the two Groups were similar and closely co-ordinated, was effected by routine telephone discussions and exchange of forecasts at first between the meteorological offices at H.Q. No. 38 Group and H.Q. Transport Command, and later between the former and H.Q. No. 46 Group. In May 1944, however, meteorological offices were opened at No. 46 Group stations whose parent forecasting office was, for geographical and administrative convenience, at first the meteorological office at H.Q. No. 38 Group, then at Netheravon. Later, when the meteorological office was set up at No. 46 Group, that office assumed the responsibility of parent forecasting unit, and the Senior Meteorological Officer, No. 46 Group, assumed full administrative control of the offices at the stations in the Group. It was not possible, however, to connect the offices at No. 46 Group stations to a teleprinter switchboard in the office at Group H.Q., but in July 1944 the latter was connected as a tail to the teleprinter switchboard in the office at No. 38 Group. This enabled the hourly weather reports from

[1] D.G.O. Org. Memo. S.D.155/1943 (1950). [2] A.M. File S.98425.

No. 46 Group stations to be received much more quickly at the Group H.Q. than at ETA. At the same time, it was arranged for the W/T broadcasts of weather reports from the British meteorological units on the Continent to be received direct at No. 46 Group H.Q. Weather reports from the Normandy beachhead had been received soon after the landing and by July it had been arranged for data to be exchanged between the forecast centre at H.Q. No. 46 Group and the meteorological unit with No. 93 Staging Post in Normandy. This developed into a more general exchange of reports with all the meteorological units of 2nd T.A.F. In August 1944, a meteorological teleprinter channel was installed from the Continent to ETA and the direct W/T reception of the broadcasts at No. 46 Group was no longer needed.

For a time, the forecast centre at H.Q. No. 46 Group provided meteorological data needed in both directions for the Croydon–Paris civil air route, but when a French forecasting unit was set up at Le Bourget in October 1944, the supply of advice for the Paris–Croydon route ceased; landing forecasts for Croydon continued to be sent to Paris and landing forecasts for Le Bourget were received in exchange. Daily discussions were started between the duty forecasters at H.Q. 46 Group and 2nd T.A.F. to co-ordinate the meteorological advice for flights to and from the Continent given by the forecast centres in the United Kingdom and with 2nd T.A.F.[1] Similar discussions were later arranged between the forecast centres at H.Q.s No. 46 and No. 38 Groups in connection with joint supply-dropping operations. In April 1945, meteorological daily conferences were also arranged between H.Q. No. 46 Group and H.Q.s No. 44 and No. 47 Groups.

The meteorological needs of No. 116 (Independent) Wing were discussed in January 1944. The requirements of the Wing H.Q. consisted essentially of the issue to Operations Staff of forecasts for day to day planning of the operations on the United Kingdom–India trunk route, and those at stations of the issue of flight forecasts to, and the briefing of, departing aircrews. It was at first thought that the meteorological office at Transport Command H.Q. should meet the needs of the Wing H.Q., but it was later decided that a forecasting office would be needed and that when this office was set up, the forecasting responsibilities of the meteorological office at Transport Command H.Q. could be considerably reduced. It was, therefore, arranged to provide most of the meteorological staff for H.Q. No. 116 Wing by transferring staff from Transport Command H.Q. At first, therefore, meteorological information was supplied to No. 116 Wing by Transport Command H.Q. and passed to the Operations Room at the Wing H.Q. by telephone. In July 1944, however, a major forecasting office was set up at the Wing H.Q. by transferring most of the staff of the meteorological office at Transport Command H.Q.

Meteorological offices had already been set up at Lyneham and Hendon and, as the type of operations at those stations did not change on their transfer to No. 116 Wing, no major adjustments to the meteorological staff and facilities at the stations were needed. In November 1944, the forecast centre at H.Q. No. 116 Wing took over from that at H.Q. No. 44 Group the responsibility for forecasting for the Mediterranean routes, but the responsibility for administering the meteorological offices at the stations of No. 116 Wing was not transferred from No. 44 Group until the end of 1944. With the forecast centre at H.Q. No. 116 Wing assuming, as its primary function, the responsibility for supplying all forecasts for Transport Command routes from the United Kingdom to the

[1] A.M. File S.103916.

Mediterranean, it became necessary for it to supply advisory route and landing forecasts to various addresses in the Mediterranean and for the recipients to provide similar information in exchange. For example H.Q., M.A.C.A.F., supplied information for routes between Marseilles and 20° E., and No. 1 (M.E.) Met. Unit at Almaza supplied information for the route 20° E. to Cairo. This routine exchange of information was constantly being revised to fit in with alterations of route and times of flight, and a routine amendment procedure was introduced in early 1945.

In January 1945, No. 116 Wing became No. 47 Group but the meteorological requirements remained the same and the forecast office at the Group H.Q. continued to be the main centre in the United Kingdom for the issue of meteorological advice for flights to the Mediterranean and Middle East. The increase in the number of flights and routes during 1945, including the Lancastrian service to Lydda, necessitated an increase in the exchange of route and landing forecasts and it became difficult to implement the amendment procedure. However, a Master Control at Malta was set up in April and the additional communications facilities provided therewith greatly facilitated in-flight amendment procedure on the air routes between the United Kingdom and the Mediterranean. A further much needed facility was provided in August by the installation of a meteorological W/T channel (T.C. 162) between H.Q. No. 47 Group and Malta. This circuit proved invaluable for exchanging route and landing forecasts, aircraft reports and warnings.

As a result of the multiplicity of routes and some overlapping between the various Groups, the Meteorological Office had to define, early in 1945, the responsibilities of the forecast centres at the H.Q. of Nos. 44, 46 and 47 Groups. Broadly, the responsibilities were allocated to various zones according to the functions of each formation. The meteorological office at Overseas Aircraft Control and H.Q. No. 44 Group provided information for flights to the Azores and on the routes to North-west Africa, that at H.Q. No. 47 Group supplied information for flights to the Central and Eastern Mediterranean and Middle East, and that at H.Q. No. 46 Group provided information for flights to the Continent. To ensure complete co-ordination, each forecast centre consulted the others as required. Early in 1945, a Senior Meteorological Officer was appointed to No. 216 Group, Transport Command, Cairo, to keep the Chief Meteorological Officer, Middle East, and the Meteorological Office informed of details of the meteorological needs of Transport Command along the United Kingdom—India route on the Mediterranean and between Cairo and Karachi. A Senior Meteorological Officer was also posted to No. 300 Wing, Australia, to act in a liaison capacity.

Overseas Aircraft Control

During 1944–45, the meteorological office at Overseas Aircraft Control, Gloucester, continued to be a major forecasting office for oversea flights, except those across the North Atlantic, and there were no major changes in the general work of that office during the rest of the war as, although the forecast centre at H.Q. No. 47 Group now supplied the forecasts for flights to the Mediterranean and Middle East bases, O.A.C. continued to control the flights. Hence the need to co-ordinate the meteorological advice of H.Q. No. 47 Group and O.A.C. The meteorological office at Gloucester continued to meet the needs of H.Q. No. 44 Group and the Senior Meteorological Officer at Gloucester

continued to serve the dual function of Senior Meteorological Officer, No. 44 Group and O.A.C. The expansion of Transport Command had been accompanied by an increase in the number of stations controlled by No. 44 Group. Type 2 meteorological offices were provided at all these stations, and special meteorological instruction was given at the O.T.U.s concerning the climate of the various regions through which Transport Command operated.

Continental Aircraft Control (C.A.C.)

The establishment early in 1945 of C.A.C., at Uxbridge to control Transport Command aircraft operating between the United Kingdom and continental bases east of the line from Selsey Bill to Sete, near Marseilles, led to a need for yet another forecasting centre in Transport Command. This need was met by providing a Type 2 office with the forecasting centre at H.Q. No. 46 Group as its parent. The main function of the meteorological unit with C.A.C. was to give advice regarding in-flight and landing conditions; in addition to close contact with its parent office, it maintained liaison with the meteorological offices at H.Q. No. 47 Group and at O.A.C., Gloucester.

Transatlantic Aircraft Control (T.A.C.)

The Prestwick meteorological office continued to meet requirements on the North Atlantic and became responsible at the end of 1944 for supplying meteorological data for flights by A.B.A. aircraft from Prestwick to Stockholm; the arrangements for these were similar to those for the B.O.A.C. flights to Stockholm from Leuchars. The meteorological procedures and practices which had been so carefully worked out for flights to and from Canada and North America were continually being improved. Various changes were made in the schedule of routine forecasts between Prestwick and Dorval, and in January 1945 an exchange of forecast analyses was introduced, using the Combined Analysis Code.

V.I.P. Flights

An important function of Transport Command was carrying ' very important persons.' Many of these flights originated in the London area and were arranged by Air Staff at the Command H.Q. The forecasting requirements were the responsibility of the meteorological office at the Command H.Q., and included pre-flight advice and information to Air Staff and the preparation of the flight forecast and briefing of the crew. Most of the flights from the London area took off from Northolt and the normal procedure was for the crew to visit Transport Command H.Q., 12–24 hours before departure for general briefing on their flight and a preliminary meteorological briefing. The final briefing took place on the airfield immediately before take-off. Most of the departures were at night. On one occasion, by arrangement with Bomber Command, Special meteorological reconnaissance flights were flown in connection with a flight by H.M. The King. ' Pampa ' flights to obtain information for special flights of Transport Command were later extended to include almost every V.I.P. flight. When the Prime Minister and his Staff flew to and from the Yalta conference early in 1945, the Head of the Transport Command Branch of the Meteorological Office took charge of the forecast centre at Transport Command H.Q., whilst the Chief Meteorological Officer of the Command went with a meteorological party to the Crimea.

Meteorological Aspects of Transport Operations

The essential meteorological need of Ferry and Transport Commands was the provision of information to enable flights to be made as safely and with as little delay, as possible. This necessitated supplying data for planning purposes and providing reliable forecasts for periods up to 24-hours or more. The assessment of the upper winds and any hazardous phenomena, such as icing *en route* and the prediction of the landing conditions at the terminal were particularly important. The tendency of Captains of transport aircraft to fly on ' actuals,' *i.e.* weather reports, rather than on forecasts, which may have been due to the fact that forecasts were not wholly reliable, especially when communications or basic data were inadequate, was a dangerous practice, particularly in areas such as Western Europe where the weather conditions may change from good to bad within minutes. Every effort was made throughout the war to perfect the meteorological organisation for long-distance flights although progress was often hindered by differences of outlook on the part of British and U.S. authorities—not so much between expert meteorologists as between the Staffs whom these experts advised.

After the successful experimental transatlantic flights in 1937, by Imperial Airways and Pan-American Airways, the Irish Government called a conference in Dublin in 1938 of representatives from the United Kingdom, the U.S.A., Canada, Eire and the two operating companies to consider drafting an organisation for future flights. As a result of this conference, which was attended by meteorological advisers, a Transatlantic Air Services Safety Organisation (T.A.S.S.O.) was produced which set out the control signals and meteorological arrangements to be followed in flights on the transatlantic route, Shannon—Newfoundland—Montreal—New York. The meteorological arrangements formed the basis of the meteorological procedures developed during the war for all the various routes operated first by Ferry, then by Transport Command, as well as for long-distance civil air routes. The essential features were the exchange of advisory forecasts between the meteorological offices at the departure and terminal airfields, the supply on a standard form of weather information both before and during flight and a uniform post-flight procedure.

The exchange of meteorological information between bases involved transmitting basic synoptic data, analyses of the meteorological situation and flight and landing forecasts. The briefing of aircraft Captains involved the supply of several documents embracing the flight and landing forecasts, actual and forecast weather maps, general inference, etc. In flight procedure involved the supply of amendments to forecasts, and weather reports for stations *en route* and at destination. Post-flight procedure involved the dissemination of information contained in the meteorological log kept during the flight. Adequate communications, standard practices and appropriate security measures were essential to implement these arrangements satisfactorily. In the case of the transatlantic routes particularly, joint measures had to be agreed between the United Kingdom, the U.S.A. and Canada. This took time and, at first, there were many differences of procedure on the military routes and also between those of the military and civil routes.[1] For example, the United Kingdom and the United States used different units and different methods for the setting of altimeters and a different base of reference for

[1] A.M. Files S.61366 and S.69270.

cloud height or ceiling. Conferences of T.A.S.S.O. were held in Dublin in 1941 and 1942 but, although a considerable measure of agreement was reached, there were some points, particularly in regard to meteorological procedure, on which it was not possible to reach a decision. Further T.A.S.S.O. discussions were held in Ottawa in September 1942 and a special meeting of the Meteorological Committee of the Combined Chiefs of Staff Committee in Washington was arranged to take place at about the same time.[1] All these meetings were attended by meteorological representatives of the countries concerned, and all matters relating to the meteorological organisation on oversea and transcontinental air routes were thoroughly discussed. As a result, general agreement was reached on the meteorological procedures and practices for the north-east ferry route and the U.S./Canada—Prestwick, Elizabeth City—Bermuda, Bermuda—Gander routes, also the south Atlantic route. New codes were adopted for sending landing reports by W/T (Alametco) and in-flight reports (Ferimet) and an intrazonal cypher was agreed for the north-east ferry route. Decisions on some details affecting the meteorological organisation for Transport Command were not reached, but agreement was later reached on most of these through the Combined Meteorological Committee, or the Allied Meteorological Committee, South-east Asia, with H.Q. in Delhi.[2]

For a long time, the American practice was to draw upper air charts showing the contours of pressure at a given height, whereas the United Kingdom practice was to draw them showing height contours for a given pressure. Eventually, the United Kingdom practice became generally accepted. In consequence of all the negotiations referred to above, a Meteorological Organisation for Overseas Flights (M.O.O.F.) was drawn up by the Meteorological Office who issued it jointly with R.A.F. Transport Command, Department of Civil Aviation (U.K.), Department of Transport (Canada) and the R.C.A.F. Transport Command. The general legislation of M.O.O.F. differed little basically from the meteorological organisation embodied in T.A.S.S.O. M.O.O.F. procedures were laid down for all the main transport routes except, provisionally, those to India and the Far East for which various factors, chiefly manpower and communications, made it impracticable to introduce a detailed application of M.O.O.F.[3] On the other hand, there was less need for full M.O.O.F. procedure on these routes because of the more settled weather conditions. Moreover, meteorological procedure on the routes to the Middle East and India did not necessitate the detailed discussions with the allied meteorological services as in the case of the transatlantic routes because most of the routes to the east passed through territory under British control. Thus, the documentation of aircraft Captains was less elaborate, and a routine exchange of route and landing forecasts between adjacent forecast centres took the place of the point-to-point exchange of advisory forecasts for individual flights. Meteorological control was exercised through Staging Posts and Air Traffic Control Centres set up along the routes, and new forecasts or operationally significant information were supplied to aircraft in flight by a system of broadcasts on a request basis. Even this system needed a detailed planning, and a senior Meteorological Office official made a special flight along the India route in 1943/44 to co-ordinate the meteorological services and to legislate for standard practices and procedures along the route.[4]

[1] A.M. File S.82001.
[2] A.M. File S.72856.
[3] T.A.S.S.O. 4th Edition.
[4] A.M. Files S.76853 and S.70587/II.

Both British and American forecast centres were set up at a number of stations on the transport routes. This also happened in the United Kingdom in the case of bomber and fighter operations but, whereas in that case a dual meteorological service working together was operationally justifiable, it is doubtful whether, in view of the need to economise in manpower and communications, such duplication was really necessary in the case of transport flights. Generally, however, most of the meteorological staff were British at stations in British territory. The meteorological and other requirements of the U.S. Air Transport Command and R.A.F. Transport Command were co-ordinated by a Joint U.S.A.A.F. and R.A.F. Board which met from time to time at the various stations concerned to consider means of implementing joint installations for the operations of the two Commands and to recommend action to ensure the co-ordination of their activities. An Assistant Director of the Meteorological Office attended the meetings of the Joint Board.

Communications

The Transport Command had particularly complicated and extensive communications requirements. The Air Ministry Telecommunications Directorate made every effort to provide the facilities required, and the co-operation of the American and Canadian authorities was also invaluable. Prestwick acted as the United Kingdom collecting centre for all weather data concerning the American continent and the North Atlantic air routes. For this purpose, a radio-telegraph circuit, with cable back-up, was provided between Prestwick and Dorval: the main exchange of transatlantic data was effected by means of this circuit. To facilitate the rapid dissemination of the data obtained at Prestwick, a teleprinter broadcast was provided from Prestwick to as many as eighteen formations and airfields directly concerned with transport flights. In addition, W/T point-to-point circuits were set up for the exchange of meteorological data between Prestwick and the Azores, Bermuda and Iceland. Radio teletype procedure was introduced at Prestwick when a U.S. radio-teletype machine for the auto-transmission of the Prestwick North Atlantic teleprinter broadcast was installed towards the end of the war.

The development in the later stages of the war of air routes to the Continent, the Mediterranean, Middle East and India involved setting up further W/T broadcast channels from Gloucester and Hendon to airfields in France and North Africa, and providing a number of meteorological point-to-point circuits between terminal airfields and the more important intermediate staging posts. Ground-to-air channels were also provided at all main staging posts on the whole trunk-route from the United Kingdom to India for the transmission of weather information to aircraft in flight.

Codes

The M.O.O.F. code, which had been developed for the exchange of route and landing forecasts on the Atlantic route, was gradually introduced on other trunk routes and, except for minor modifications, it remained in use until the end of the war.

Before the war, aircraft flying on trunk routes commonly transmitted weather observations made during flight to their ground bases by W/T in order to provide current meteorological information along the routes and thus to

supplement the available surface data. During the war, this procedure was suspended on nearly all civil air routes owing to the need to maintain W/T silence and to deny valuable information to the enemy. On the North Atlantic route, however, where the need for W/T silence was less than elsewhere and the need for reports was great, a simple scheme ('Ferimet') was devised whereby aircraft weather reports could be coded, encyphered and transmitted to bases on control frequencies.[1] Such reports were made at specified intervals, usually hourly, or at particular points along the routes, in accordance with requirements previously decided at meteorological briefings. The reports normally gave information on: aircraft position; aircraft altitude; wind direction and speed at flying height; sky condition; general weather; aircraft icing; and air temperature. The precise construction of the Ferimet code was constantly reviewed and modified during the war, in the light of experience and in close consultation with the meteorological services of the United States and Canada. By April 1945, in accordance with a Transport Command Air Staff Instruction, Ferimet had been brought into use on all Transport Command trunk routes. The code was not, however, as comprehensive as could be desired nor as comprehensive as that used by meteorological reconnaissance aircraft. The Combined Meteorological Committees discussed the best code for in-flight weather reports, but no agreed code was produced until February 1945. This was the Combined Aircraft Weather Report Code (CAW-C) and it provided for various types of in-flight and post-flight reports including reconnaissance reports. It was not promulgated by the Meteorological Office, however, until August 1945.[2]

The Alametco code was introduced in August 1943 for the supply to aircraft in flight by broadcast or on request, of weather reports for landing (Aircraft Landing Meteorological Conditions).[3] It was adopted in view of the extensive use of R/T, especially in the U.S.A.A.F., and the consequent difficulty in dealing with a code of the subtractor type which had previously been used. The Alametco code was used both in the United Kingdom and overseas by R.A.F. and U.S.A.A.F. transport aircraft and by civil aircraft,[4] but it was not an easy code to use, and a new code, UCO, which had been approved by the Combined Meteorological Committee, was introduced for universal use in September 1944. There were three versions: UCO (Request), UCO (Broadcast) and UCO (Plain).[5] The first enabled an aircraft Captain to obtain the particular items he required, the second enabled certain standard items to be broadcast at specified airfields where the large traffic made it necessary to avoid a large number of requests, and the third was for use in areas where there were no security restrictions and could be used to supply information on request or by broadcasts. The code, which was of great value on transport routes, was brought into use for non-operational transport aircraft on 1 January 1945, and was in general use at the end of the war. An interesting development was the growth of UCO half-hourly or hourly broadcasts for reports and forecasts of landing conditions, and the introduction of UCO 'collectives' whereby information for several stations was given in a consolidated broadcast especially at centres such as O.A.C. and C.A.C.

[1] A.M. File S.93369.
[2] Synoptic Instruction No. 156.
[3] S.D.I. No. S.104.
[4] S.D.I. No. S.43.
[5] S.D.I. No. S.114.

CHAPTER 12

ARMY AND COMBINED OPERATIONS

Army

On the outbreak of war, no meteorological units were provided for the Army in the United Kingdom, except at the permanent War Office Establishments such as Larkhill, Shoeburyness and Porton, although meteorological units had been provided at Artillery Practice Camps as and when required. In fact, before, and in the early days of the war, the general practice was for R.A.F. meteorological units to provide the Army with any meteorological information required. For the B.E.F. in France, the meteorological section of the H.Q. R.A.F. Component dealt with the meteorological requirements of the corresponding Army H.Q.; detachments of meteorological personnel were allocated to Survey Regiments and to anti-aircraft batteries. In fact, plans had been made in 1939 for the Army itself to obtain the local weather observations required for gas warfare purposes and for smoke-screens by using specially trained and suitably equipped R.E. personnel. These plans were, however, never fully implemented owing to a later proposal to form a meteorological organisation for the Army, but the specially trained R.E. personnel of the Chemical Warfare Units were retained until such units were abolished early in 1943 and were employed at the Chemical Warfare practice camp which opened in the Exmoor area in December 1940. By June 1940, Shoeburyness and Porton had been transferred to the Ministry of Supply. At Larkhill, a radio directional wind finding unit of the Meteorological Office had been set up and meteorological units were supplying meteor reports (both anti-aircraft and flat fire) at ten Artillery Practice Camps and at Falmouth Coast Defence Unit.

Development of a Meteorological Organisation for the Army

It was decided in June 1940, to post a Meteorological Liaison Officer to G.H.Q. Home Forces and to each of the Army Command H.Q., *e.g.* Northern, Southern, Eastern, Western, Scottish and Northern Ireland,[1] and to provide forecasting sections at Corps H.Q. In pursuance of this policy, a Meteorological Officer was posted to the H.Q. of each of ten different Army Corps to act in an advisory capacity, particularly in regard to the meteorological aspects of Chemical Warfare. In addition, meteorological units were provided at Army Divisional H.Q.; part of their duties was to supply information to the Chemical Warfare Units. Advice and guidance were to be given to each of these units by the most convenient Type 1 meteorological office in the vicinity.

In August 1940, an establishment of meteorological personnel at G.H.Q. Home Forces and at H.Q. of six Army Commands, twelve Army Corps, fifteen Divisions, five Mobile Met. Units and for the 1st Survey Regiment was approved. The meteorological unit attached to the 1st Survey Regiment was engaged on work connected with Sound ranging on enemy guns across the English Channel.[2] In September 1940, the Northern Ireland Army Command

[1] A.M. File S.62148.
[2] A.M. File S.37349.

became merged in a bigger organisation—' British Troops in Northern Ireland ' —and the meteorological service with the R.A.F. then became responsible for supplying meteorological information to the military authorities in Northern Ireland. In December 1940, a meteorological section was supplied to the newly appointed Chemical Warfare Practice Camp in the Exmoor area, and in February 1941, a meteorological section was provided at the H.Q. of the new South Eastern Command.[1]

It was soon found that, during Army exercises, the meteorological sections at Divisional H.Q. did not function as well as could be wished, due mainly to inadequacies in the method and system of communications by which the Meteorological Officer had to get the basic weather information from the Central Forecasting Office. The Army was responsible for providing signal facilities but no special or additional facilities were provided as the War Office felt that the normal signals services provided for Army purposes would be able to deal with any additional work for meteorological sections. In practice, little or no signal facilities were available to these sections owing to priority operational requirements. This deficiency was emphasised after Army Co-operation Command had been formed in April 1941 ; Squadrons attached to particular Army Groups or Armoured Divisions flew from airfields adjacent to the Army H.Q. to which they were attached but obtained their meteorological information how and when they could from the nearest R.A.F. meteorological office.

A Senior Meteorological Officer was posted to Army Co-operation Command H.Q. in May 1941 and recommended that the squadrons' primary source of meteorological information should be the meteorological sections of the H.Q. of the Corps in whose area the Squadrons were required to operate. A subsequent meeting of Meteorological Office and War Office representatives led to a re-organisation of the meteorological service for the Army. The meteorological section of Corps H.Q. were to be expanded to provide a full 24-hour forecasting service in order to serve the Army in the Field as a whole and also to meet the meteorological requirements of the Army Co-operation Command Squadrons. The meteorological sections of Divisional H.Q. had not been a success and were abolished, but one officer was included in the enlarged meteorological section of Corps H.Q. whose primary duty was to maintain close liaison with the Army user formations, *e.g.* chemical warfare, smoke screening, artillery, etc.[2] Provision was also made for a full 24-hour forecasting service at G.H.Q. Home Forces whose Senior Meteorological Officer acted as Meteorological Liaison Officer to Army Co-operation Command H.Q. The small advisory and co-ordinating meteorological sections of Army Command H.Q. were retained. The War Office agreed to meet all the needs of the meteorological sections in respect of accommodation, messing and transport, but still insisted that it was not necessary to provide the sections with their own W/T equipment.[3]

It became increasingly clear in 1941 that the most serious difficulties of the meteorological sections of Army units were related to communications. Various means of getting essential information from a convenient source were tried, *e.g.* from a nearby meteorological unit with the R.A.F. by telephone or dispatch rider, but all proved unsatisfactory ; forecasts and Meteor reports were often out of date by the time they reached their destination. While conditions

[1] A.M. File S.62700.
[2] A.M. Files S.69274 and S.37349/II.
[3] A.M. File S.37349.

were static, the only satisfactory solution was to provide the Army meteorological sections with a teleprinter connected to the main meteorological teleprinter network so that data were readily available for forecasts and Meteor reports to be prepared on the spot. The dissemination of the data to lower Army formations would then be the responsibility of Army signals. It was realised that under operational conditions W/T would be the only reliable rapid means of communication. Such teleprinter facilities were accordingly provided at G.H.Q. Home Forces in March 1941 and also at the Corps meteorological sections by the time the reorganisation was completed in October 1941. The dissemination of meteorological information to lower formations remained the responsibility of Army Signals.

Exercise ' Bumper ' in December 1941 again stressed that, under operational conditions, adequate W/T facilities would be needed for the meteorological sections and the War Office were asked to re-consider the provision of W/T equipment for the forecasting sections of Corps H.Q. In January 1942, they agreed to provide transport and W/T operators but not the W/T receivers themselves. It was, therefore, arranged in February 1942 for the Air Ministry to provide the W/T receivers required and, by June 1942, most of the meteorological sections were so equipped. By this time, Wing H.Q. of Army Co-operation Command had been set up at each of the Army Command H.Q. at Home. Meteorological information required by a Wing H.Q. was obtained by the meteorological section of the corresponding Army Command H.Q. after consultation with the forecasters at Corps H.Q. or at the nearest R.A.F. meteorological unit. Exercises in early 1942 showed that without adequate signal facilities the meteorological sections of Corps H.Q. could not provide satisfactorily the meteorological information required for the effective operation of aircraft over the battle area especially as the aircraft were controlled by Wing H.Q. at Army Commands. This led to a demand for a full forecasting unit at Army Command H.Q. and for the provision of meteorological personnel at the airfields from which the Army Co-operation Command squadrons actually operated. In October 1942, the additional forecasters and assistants were provided. The R.A.F. had agreed in August 1942 to provide full W/T facilities for all the meteorological sections of Army formations and an establishment was approved in October 1942, but the W/T equipment was not provided until February 1943.[1] The War Office had agreed to supply 30 cwt. trucks for the mobile meteorological units attached to the Corps Meteorological Sections and mobile offices for the latter, but experience in the field showed that the vehicles so supplied were unsuitable and that a specially designed vehicle was needed for a forecasting unit.

Once adequate W/T facilities were available, the question arose of suitable codes for disseminating forecasts and reports. A code was already in use for passing meteorological information relating to Chemical Warfare, and the War Office approved the use of pad cyphers for passing such meteorological messages when encyphering was considered essential. It was also agreed that the meteorological sections of Army formations could pass Meteor reports *en clair* when other operational messages were also being passed uncoded.[2]

By early 1943, except for the Sound Ranging meteorological units and the meteorological section of the Chemical Warfare Practice Camp, the meteorological units with the Army and with Army Co-operation Command had

[1] A.M. File S.69285.
[2] A.M. File S.60589.

become so inter-linked and the requirements so interwoven that it was difficult to separate their establishments. It was, therefore, decided to transfer most of the meteorological personnel with the Army formations to Army Co-operation Command.

The position when Exercise 'Spartan' began in March 1943 was that forecasting units were provided at G.H.Q. Home Forces and at six Wing H.Q. attached to Army Command H.Q.; small reporting and distributive meteorological units were also provided at airfields from which the Army Co-operation Command squadrons operated, whilst special meteorological sections were provided at Sound Ranging Units and at the Chemical Warfare Practice Camp. As a result of the experience gained during the Exercise and of the fusion of Army Co-operation Command into Fighter Command (2nd Tactical Air Force) in June 1943, the whole organisation for meeting the meteorological requirements of joint Army/R.A.F. formations was recast.

Artillery Practice Camps[1]

On the outbreak of war, meteorological personnel were attached to the Artillery Practice Camps then operating in order to supply Meteor reports to the artillery units on the camp. By June 1940, meteorological staff were on duty at ten Artillery Practice Camps and at the Coastal Defence Unit at Falmouth. In view of the satisfactory results of a procedure, introduced in November 1941, for appropriate Meteor reports to be supplied, on a centralised basis from a number of Type 1 or 2 meteorological offices, at regular 4-hourly intervals to all A.A. Gun Sites, it was suggested to the War Office in February 1942 that this system could be extended to the Artillery Practice Camps, the idea being to save trained meteorological personnel. The War Office would not agree, however, and the meteorological staff were maintained at the Artillery Practice Camps throughout 1942 and 1943. They were not withdrawn for service elsewhere until May 1944, by which time most of the camps had closed. By 1944, the main work of the meteorological staff at Artillery Practice Camps was to prepare Meteor reports for calibration trials of the different types of guns; the necessary meteorological information had to be obtained from a nearby meteorological office which also supplied forecasts as supplied.

Sound Ranging

At the outbreak of war there was a meteorological section of the School of Survey at Larkhill where cadet officers were trained in sound ranging procedure, but no meteorological personnel were provided for operational work with Sound Ranging Batteries in the Field.[2] It had been envisaged that in wartime meteorological units would be required for sound ranging purposes, and meteorological detachments were allocated to the Survey Regiments with the B.E.F. in France, but it was not until August 1940 that the War Office agreed an establishment of meteorological personnel for the 1st Survey Regiment[3] and a meteorological unit was posted for duty with the Sound Ranging Battery of the Regiment. By October 1940, this Sound Ranging Battery was working on enemy guns in France, and, details of wind and temperature structure in the upper air were supplied to the meteorological unit of the Battery from the meteorological Office at H.Q. No. 11 Group, R.A.F., at Uxbridge. In November 1940, in view of its specialised work in connection with the location of enemy

[1] A.M. File S.60865. [2] A.M. File S.62871. [3] A.M. File S.37349.

guns across the Channel, this particular Sound Ranging Battery became an independent unit known as the 1st Independent Sound Ranging Battery. The meteorological section of the 1st Survey Regiment was transferred to the new unit on the understanding that if and when a new Sound Ranging Battery was formed for the 1st Survey Regiment, another meteorological section would be provided. This did not arise until May 1941.

The War Office asked in November 1940 for a meteorological section to be provided for the 4th Survey Regiment. This was duly provided and the Regiment with its meteorological section left for the Middle East almost at once. In the following month, it was arranged for meteorological sections to be established for two more Survey Regiments; one was supplied to the 2nd Survey Regiment in February 1941 and the other to the 1st Survey Regiment in May 1941. These sections were provided with a 30 cwt. truck specially adapted to facilitate easy and safe stowage of meteorological equipment.

The War Office announced their intention in May 1941 to have nine Survey Regiments which would each have a Sound Ranging Battery divided into two troops, both of which would be liable to function on different Divisional fronts and both of which were to have a Meteorological Officer and four assistants. The War Office issued in July 1941 a priority list giving the order in which the meteorological sections of Survey Regiments should be provided and, as a result, the meteorological section of the 2nd Survey Regiment was transferred to the 5th Survey Regiment. The shortage of trained personnel made it impossible for some time to provide the additional meteorological sections required, but suitable personnel were selected for an intensive but short course of training at Larkhill; some meteorological officers were trained at Larkhill in the operation of sound ranging units as well as specialist training in the meteorology of the subject. As a result, it was possible in July 1941 to provide the 2nd Survey Regiment with the nucleus of a meteorological section to replace the section transferred to the 5th Survey Regiment, and the War Office continued to press for the early provision of meteorological sections for the other Survey Regiments. By the end of 1941, enough trained meteorological personnel were available to bring the meteorological section of the 2nd Survey Regiment up to strength and to provide a complete section for the 3rd Survey Regiment. This new section was stationed in N. Ireland and joined in exercises held in mid-January; it left with the Regiment for overseas in January 1942.

The War Office agreed in January 1942 that the officers-in-charge of Sound Ranging Meteorological Units should be replaced by a senior assistant, *i.e.* a Flight Sergeant. The change-over was effected by June 1942 after suitable N.C.Os. had been posted to Larkhill for refresher courses. The officers so released were employed in the 24-hour forecasting sections of Corps H.Q. and the postings were so arranged as to ensure wherever practicable that each Corps Meteorological Section included a meteorological officer with experience in the field of the meteorological aspects of sound ranging. At the same time the meteorological sections of Survey Regiments were placed under the supervision of the meteorological officer at Army Corps H.Q.

The work of the meteorological sections under a Flight Sergeant proceeded smoothly. The section with the 5th Survey Regiment went overseas with the Army to North West Africa and the section with the 1st Independent Sound Ranging Battery was, on the disbandment of that unit in December 1942,

transferred to No. 7 Survey Regiment. By January 1945, the 1st, 2nd, 3rd and 5th Survey Regiments with their meteorological sections had gone overseas. By that time, the 9th Survey Regiment had been formed and was provided with a meteorological section as was No. 8 Survey Regiment which mobilised immediately and proceeded overseas. Later in January 1943, the War Office asked for meteorological sections to be posted for duty with Nos. 10 and 11 Survey Regiments. Staff were trained in readiness to meet with this request but were temporarily diverted to take part in exercise 'Spartan', on the completion of which the 10th and 11th Survey Regiments were provided with the meteorological sections required.

Canadian Army[1]

When it was decided in June 1940 to provide meteorological sections for Army Divisional H.Q., meteorological personnel were posted to the predominantly Canadian Army Divisions of the British VII Corps. Meteorological sections were provided for other Canadian Divisions as they arrived in the United Kingdom and were incorporated into VII Corps. The G.O.C. VII Corps was interested in the idea of 'Air Burst Ranging' whereby the visual observation of shell-burst in the air above a target might provide a useful alternative to Meteor reports when the latter were unobtainable owing to the lack of communications. The meteorological section of the Corps H.Q. helped in October 1940 to develop graphical methods for use in connection with 'Air Burst Ranging' but the idea was not developed. The section also worked with the portable C.W. equipment in providing data for the formulation of rules for forecasting the vertical velocity gradient at 1 and 2 metres above ground.

By December 1940, the Divisions comprising VII Corps were entirely Canadian and the Corps was renamed 'Canadian Corps'. The British meteorological personnel remained with the Corps. They experienced the same communications troubles as did the other Army meteorological sections, but during the Canadian Corps exercise in June 1941 they showed how the delay in getting information to lower formations could be greatly decreased. They did this by issuing dummy Meteors by W/T in clear over Army channels to the user units in the field and thus anticipated the provision of W/T facilities for meteorological sections of Army units and the subsequent War Office approval for transmitting Meteors in clear when other operational messages were being so passed. By July 1941 a Canadian Survey Regiment had arrived in the United Kingdom and the British meteorological officer with the Canadian Corps attended a course at Larkhill on the meteorological aspects of sound ranging so that he could assist in the formation of a meteorological section for the Sound Ranging Battery of the Canadian Survey Regiment. During the autumn, this meteorological section assisted in the calibration of the guns of the 3rd Canadian Division, some of which were of American design necessitating the provision of new weighting factors which were compiled and supplied by M.O.8.

The Canadian Military H.Q. decided to follow the British policy of providing a full 24-hour forecasting service at H.Q. Army Corps, and to staff their meteorological organisation with suitably qualified Canadians recruited from Canadian Army personnel; proposals were formulated and referred to Canada for approval.[2] Meanwhile, action was taken to train three Canadian officers and three other ranks in meteorology at the Meteorological Office Training

[1] A.M. File S.81714.

[2] A.M. File S.51773.

School. By August 1941, three other ranks had been trained and posted to the meteorological section of Canadian Corps, but the selection of suitably qualified officers was more difficult and it was not until February 1942 that the first Canadian Meteorological Officer had been trained and posted for duty with the Corps meteorological section. In January 1942, Canada approved the proposed meteorological establishments: a meteorological teleprinter was immediately installed at Canadian Corps H.Q. and a full 24-hour forecasting service was begun. By March 1942, more Canadian other ranks had been trained and the assistant staff was up to strength; in April 1942 the section assumed responsibility for supplying meteorological information to the Canadian squadrons of Army Co-operation Command at Odiham. In May 1942, the meteorological section of Canadian Corps became mobile and took part in the battle exercise 'Tiger'.

This exercise again stressed the need for improved communications facilities for Army meteorological units. It also revealed some inadequacies in the existing meteorological broadcasts which were not designed to provide, in particular, the information which experience had shown to be essential to meteorological units operating with the Army in the Field. As a result, a special routine W/T broadcast was started by ETA in July 1941. Requests were soon made for this broadcast to be expanded and encyphered in pad cyphers already available to Army meteorological sections. A revised broadcast ('ALFIG') began on 28 August 1942.[1]

The meteorological section of Canadian Corps H.Q. supplied forecasts to the Operations Staff in connection with the Dieppe raid on 19 August 1942. In the same month, following the provision of full 24-hour W/T facilities for the meteorological sections of British formations, a new Canadian establishment for their meteorological sections was approved and included four W/T operators for each section. Also during August, the officer strength of the meteorological section of Canadian Corps was completed. In September 1942, the remaining British personnel were withdrawn and the section became entirely staffed by Canadian Army personnel.

Technical Problems

A number of technical problems arose from the meteorological requirements of the Army, the most outstanding being that of forecasting for several days ahead. Whereas the R.A.F. needed reliable advice in considerable detail regarding the weather conditions at base, target and *en route* for a period generally from 12 to 24 hours ahead, the Army wanted to know, in more general terms, what the weather would be in the operational area in 2 or 3 days time or more. The limitations of existing knowledge and available data had restricted the range of reliable forecasts in a country with such variable weather as the United Kingdom to a period, normally, of 24 hours. The problem of extending this range had been studied before the war but without any real success, although accurate 'further outlooks' and warnings of spells of settled or unsettled weather had often been issued, but chiefly when the meteorological situation was steady. During the War, this problem was investigated both by the Allies and the enemy, and, with the additional data available, some progress was made. This progress, however, consisted mainly of obtaining a deeper

[1] A.M. File S.74224.

insight into the physical processes involved and indicated the lines along which further research should be carried out. Much still remained to be done at the end of the war.

The main problem in regard to the supply of Meteor reports for artillery was providing accurate upper wind and temperature data. Considerable progress was made during the war with the experience and knowledge gained from the extended use of upper air charts. Nevertheless, at the end of hostilities, the assessment of winds at very high levels called for more data and more study, not only for high firing guns or rockets but also, with the development of jet aircraft.

Finally, there was the problem of meteorological factors in relation to 'trafficability'. This was specially investigated by M.O.9, assisted by a meteorologist with a knowledge of geology. As a result of this investigation, S.D.T.M. No. 82 'Trafficability as affected by Rainfall and Evaporation' was published. Further work was done on this problem during the war, but the results were not published.

Much valuable meteorological information was supplied by the Investigations Branch of the Meteorological Office to the authorities responsible for strategic planning and important decisions were based on this information in respect of operations in Northwest Europe and other areas overseas.

Airborne Operations

It was decided in July 1940 to open a paratroop training school at Ringway, and the Air Ministry agreed to provide the school with an anemometer. This decision was referred to the Meteorological Office for action, and so began the connection of Meteorology with Airborne Operations which was to lead to the formation of a group of meteorological offices (No. 38 Group), the forecasting for almost nightly operations over enemy territory, and for the vast paratroop and glider operations in Normandy in June 1944, at Arnhem in September 1944 and during the crossing of the Rhine in March 1945.[1]

A three cup electric anemometer was fitted at Tatton Park, the actual paratroop dropping area, four miles S.W. of Ringway, on 26 July 1940. It was soon deduced that parachuting was unsafe if the surface wind was greater than 15 m.p.h. and gusty, whereas steady winds up to 25 m.p.h. were not dangerous. To investigate this point further, the Commanding Officer applied for a recording anemometer, and as a result, the Meteorological Officer, Speke, visited Ringway and recommended that a Dines anemometer and forecasting staff should be provided for Ringway, the latter both for the parachute training and for No. 3 Ferry Pool, recently formed at Ringway.[2] These recommendations were approved, a forecaster arrived in November 1940 and the Dines anemometer was erected in February 1941 on the control tower, with the recording dials in the meteorological office below.

Senior officers of the Meteorological Office visited Ringway and Tatton Park in April 1941 and receommended that past data on the effect of weather on parachuting should be analysed, and that there should be close co-operation between the Meteorological Office, Ringway and the Operational Staff. An

[1] A.M. File S.62958.

[2] A meteorological office had been opened at Ringway in August 1940 after being closed since the outbreak of war.

important result of this visit was the posting to Ringway in May 1941 of a meteorological officer who had been working on atmospheric gustiness and turbulence at Cardington; he was to begin research into the meteorological aspects of airborne operations and was attached directly to the Airborne Forces establishment at Ringway.

A report in December 1941 by the Meteorological Officer, Ringway, analysing the winter weather conditions there, showed that very few hours were really suitable for parachute dropping since either the visibility was too low or the wind too high; he suggested that more suitable conditions might be found in the Salisbury Plain area. Later, large scale parachute and glider training did take place in the Salisbury Plain area, but the better weather in that area was probably subsidiary to the fact that large Army formations were already established in the region.

Establishment of Glider Training Schools

In the second half of 1941, after initial towing experiments at Ringway, glider training was rapidly expanded. No. 1 Glider Training School formed at Thame in June 1941 and was visited soon after by the Meteorological Officer, Ringway, to ascertain the meteorological requirements; these were primarily the supply of routine forecasts including estimates of gustiness and visibility. No. 2 Glider Training School, with similar meteorological requirements, formed at Weston-on-the-Green in December 1941, and it was arranged for the Type 1 meteorological office at H.Q. No. 92 Group to supply routine forecasts and warnings to both stations.

It was noted in May 1942 that very poor results were being obtained by pupils at the Glider Training Schools in the meteorological examinations of the Central Examination Board. This was due to the subject being comparatively new to the pupils and to the shortness of the four-week course. In July 1942, the course was extended to eight weeks and in August 1942, when all Glider training came under Training Command, a new meteorological syllabus for Glider Training Schools, based on the revised Glider Manual, was drawn up.[1]

By September 1942, there were five Glider Training Schools and one Glider Instructors' School. To ensure that their meteorological needs were being met satisfactorily, an officer from M.O.6 visited all the Glider units in January 1943. In most cases, there was no local meteorological office, routine forecasts, warnings and route forecasts being obtained by tie-line from the nearest meteorological office and meteorological instruction being given by R.A.F. officers who had passed the S.N.I. course at Cranage.

In September 1942, U.S. Air Ground Support Units were set up at several airfields in the United Kingdom, and to familiarise the American meteorological personnel attached to these units with British codes and methods, a number of British meteorological officers were attached for a few months as liaison officers.

Advanced Airborne Training

In November 1942, No. 42 O.T.U. Ashbourne, with its satellite Darley Moor, was opened as an advanced training school for pilots engaged in airborne work, long day and night cross country flights being undertaken, the routes covering

[1] A.M. File S.69294.

almost the whole of the British Isles, except Northern Scotland. No paratroops were dropped during this advanced training, but legs on cross country flights were often flown at 500 feet to simulate parachute dropping, and containers with parachutes were occasionally dropped from this height in selected areas. A Type 3 meteorological office was opened at Ashbourne in November 1942 and obtained guidance from the Type 1 office at 93 Group H.Q. In view of its position, Ashbourne was selected as a synoptic reporting station and started full 24-hourly observations in January 1943.

Meteorological staff lectured to the pupils (four hourly lectures to each course) and, by local arrangement, Forms 2330 (forecast forms on the back of which actual weather conditions encountered were written by the pupils) were ' marked ' by the meteorological officers and returned to the flights so that the pupils would know how their weather reporting was progressing.

Control of the meteorological office at Ashbourne passed, in February 1945, to the new forecast centre at Shawbury. A little earlier the meteorological office at Ashbourne had been upgraded to Type 2. In March 1945, No. 42 O.T.U. component at Ashbourne moved to Tilstock and was absorbed in No. 81 O.T.U. while the meteorological office staff at Ashbourne went to Saltby. As the pupils at No. 81 O.T.U. had had preliminary meteorological lectures at their previous flying schools, meteorological instruction at Tilstock, where there was a Type 3 office, was largely confined to practical discussion on the charts, although a routine meteorological lecture on the conditions for airbourne work was given to each course.

In July 1944, the direct tie-lines between Tilstock and the parent forecast centre at H.Q. No. 93 Group were removed, and to overcome this difficulty, the meteorological office was upgraded to Type 2 in October 1944. After October, glider-towing cross country and local flights at Tilstock and its satellite at Sleap increased considerably and the difficulties of inadequate communications became rather serious. However, in January 1945, the meteorological teleprinters at Tilstock and Sleap were connected to the Shawbury Type 1 office which then became the parent office for Tilstock and Sleap.

Development of a Meteorological Service for Airborne Operations

While parachute and glider training were proceeding, the general organisation for airborne operations was taking shape. Early in 1942, the establishment was approved of a Type 1 meteorological office at H.Q. No. 38 Wing Army Co-operation Command, Netheravon, with Type 3 offices at the outstations of the Wing. The Senior Meteorological Officer at the Type 1 office was to be responsible for guiding the investigation work in connection with the meteorology of parachuting and gliding and for supervising the meteorological staff left at Ringway for that purpose. The Type 1 office at Netheravon opened in March 1942 under the Meteorological Officer from Ringway, but it was not until January 1943 that enough staff were available for a 24 hours forecasting service. The main recipients of meteorological information from the Netheravon office were Nos. 296 and 297 Squadrons based at Netheravon, the Airborne Division, the Air Landing Brigade and the Bulford Balloon Crew. At Bulford, there was a barrage balloon with a large basket in which trainee parachutists were raised to about 500 feet to practise jumps. At the end of 1943, No. 38 Wing became a Group, and a considerable increase of stations followed.[1]

[1] A.M. File S.79940.

Preparations for large scale operations were made early in 1944, and outstations were divided into training and operational sections. In March and September 1944, major regroupings of the operational stations took place, first to a concentration in the Oxford area and southwards, preparatory to the Normandy landing and later, Arnhem operations, and secondly to Essex to prepare for the Rhine crossing. During the first half of 1944, the meteorological offices at the operational stations were gradually upgraded to Type 2. Since airborne flights were usually on a large scale with many units taking part, it was essential that an agreed forecast should be issued by the Group meteorological office. To achieve this, the independent forecasters at the Type 2 offices discussed the preparation of the operational forecasts with the duty forecaster at the Type 1 office and were able to give useful advice regarding local weather conditions at the stations.

It had already become clear that a meteorological teleprinter switchboard was essential for the meteorological office at H.Q. 38 Group to give effectively the advice and guidance needed by the associated Type 2 and 3 offices. It had been agreed in April 1942 that the meteorological switchboard at Old Sarum should be moved to Netheravon, but technical difficulties precluded the move. Meanwhile, Netheravon had to distribute all forecasts by telephone, and it was not until May 1944 that work on the new switchboard began.[1] In the next few months, most of the meteorological offices at the No. 38 Group stations were connected to this new switchboard and by June, observations from No. 38 Group stations were being collected hourly and transmitted to ETA for re-broadcast.

No. 38 Group and its operational stations moved to Marks Hall, Essex, at the end of September and early October 1944. By 11 October, first and second channel broadcasts were being obtained at Marks Hall from the Central Forecasting Office, and by the end of the month most of the meteorological offices at the new stations had been connected to the teleprinter switchboard at Group H.Q., including the U.S.A.A.F. stations at Chipping Ongar, Boreham and Stanstead.

Large Scale Exercises

In February 1944, an Airborne unit of the U.S.A.A.F. joined for the first time in the large scale airborne exercises of No. 38 Group. The U.S.A.A.F. unit concerned was the 9th Troop Carrier Command (T.C.C.) and the Chief Weather Officer, 9th T.C.C., with the British Meteorological Liaison Officer with the U.S.A.A.F., visited H.Q. No. 38 Group in February 1944 for detailed discussions with the Senior Meteorological Officer. It was agreed that for future exercises, there would be telephone discussions between the forecasters of No. 38 Group and 9th T.C.C. so that an agreed forecast could be prepared. A large scale airborne exercise took place successfully in March 1944 involving consultations between the meteorological offices at 9th T.C.C., Nos. 38, 10 and 11 Groups R.A.F., the two latter Groups providing fighter cover. The control of the exercise was at No. 38 Group and the Senior Meteorological Officer was responsible for briefing the A.O.C., who had to make the final decision.

A Combined Troop Carrier Command Post was established at Eastcote in April 1944 to control all large scale airborne exercises or operations in which both British and American forces were to join, and was staffed by British and

[1] A second channel, ETA–38 Group, had already been completed in April.

American personnel. From the beginning, a small American meteorological office was set up at Eastcote, but for the first combined exercise on 19–22 April, the Senior Meteorological Officer, No. 38 Group, was the only British meteorological representative. He used the facilities of the American meteorological office and kept in touch with his own Group by telephone tie-line. Final meteorological decisions were made as a result of consultations between the Chief Weather Officer, 9th T.C.C., and the Senior Meteorological Officer, No. 38 Group, and were communicated to the A.O.C., No. 38 Group, and the General Commanding 9th T.C.C. who were both at Eastcote. After this exercise, an office at Eastcote was made available for the use of meteorological staff of No. 38 Group and 9th T.C.C. and meteorological staff were detached from No. 38 Group. For combined U.S.A.A.F.–R.A.F. airborne exercises, the British forecaster at Eastcote acted as liaison officer between the meteorological services of the R.A.F. and U.S.A.A.F.

Enough equipment and staff had been assembled at Eastcote by June 1944 to run a complete forecasting office, teleprinters having been already connected to receive first and second channel broadcasts from ETA. The Senior Meteorological Officer, No. 38 Group, was responsible jointly with the Chief Weather Officer of 9th T.C.C. for issuing the forecasts for the airborne landings which immediately preceded the general landing on the Continent on 6 June and for subsequent forecasts for further smaller scale airborne operations.

After this very busy period in early June, the Senior Meteorological Officer, No. 38 Group, controlled the meteorological side of the night operations, when supplies and agents were dropped by parachute on the Continent. Just previously, the Senior Meteorological Officer, No. 46 Group, was temporarily attached to No. 38 Group, in order to see the forecasting for airborne exercises and operations in which stations of his Group would be joining with No. 38 Group and, in due course, daily consultations were arranged between the forecasting offices of these two Groups.

Routine Night Operations of No. 38 Group

Forecasts and outlooks were given to the A.O.C. and Air Staff regularly throughout the day for the regular night flights which were being made by No. 38 Group aircraft over the Continent to deliver agents and supplies to Resistance Movements. The usual daily routine was for the Senior Meteorological Officer or the duty forecaster to attend a conference in the War Room, after a telephone conference with Eastcote when the forecasting office had been set up there, and to give an account of the weather over the British Isles and a large part of Europe during the past 24 hours; this was then discussed in relation to the results of the previous night's operations. Many targets over wide areas of Europe were available to No. 38 Group who usually chose those where it was possible to drop men or supplies, *i.e.* where good breaks in the cloud would allow aircraft to descend to about 500 feet and see the lights laid out by agents on the required dropping zones and, in the case of dropping agents, where the surface wind was not too great. During the discussion, the general meteorological prospects for the next night were given and the targets best suited to the forecast weather situation were selected. The prospects for landing operations in the early hours of the following morning were, of course, taken into account and the probability of diversions was considered. Further, such briefings were given by the Senior Meteorological Officer or the duty forecaster

during the day, ending with the final operations forecast which was telephoned to the meteorological offices at the Operational stations for the briefing of aircrew. During the day, the forecasters at No. 38 Group were constantly in touch with the meteorological offices at the stations by means of routine telephone conferences. The question of diversions at the end of long operational flights was often important, and other meteorological offices were consulted in advance.

First Allied Airborne Army (F.A.A.A.)

The First Allied Airborne Army was formed on the 8 August 1944, and an American G.O.C. took charge of all the available airborne forces including No. 38 Group, No. 46 Group and 9th T.C.C. On 9 September, the Senior Meteorological Officer, No. 38 Group, was appointed as British Meteorological Officer to F.A.A.A. in addition to all his other duties. He remained at F.A.A.A. until 23 September.[1] At the same time, the Chief Weather Officer of 9th T.C.C. was appointed as American Staff Weather Officer to F.A.A.A., retaining his post as Staff Weather Officer of 9th T.C.C. An American weather office already existed at F.A.A.A., and the British Meteorological Officer worked with the information available in this office. Several large scale airborne operations were planned and meteorological briefings were given jointly by the British and American meteorological advisers. The Allied Army on the Continent made such good progress, however, that each operation in turn had to be abandoned as the projected area was over-run.

Arnheim Airborne Operation

On receiving a favourable forecast for the next few days on 16 September, 1944, the G.O.C., F.A.A.A. took action to land a large part of First Allied Airborne Army in Holland. These airborne landings were made from 17–25 September inclusive, and detailed meteorological advice was given throughout the period. Radio contact was maintained for some time with the British 6th Airborne Division and some weather reports were sent by them to Group H.Q. A full account of the forecasts and meteorological advice supplied during this operation and the actual weather encountered was sent to Meteorological Office H.Q.[2]

Immediately after the Arnhem operation, it was decided to close down the now redundant T.C.C.P. at Eastcote and transfer the remaining staff to F.A.A.A., so that full preparations for further operations could be made. The British meteorological staff moved on 29–30 September and were accommodated next to the American Weather Office.

Container Dropping from Medium Heights

Partly as a result of the Arnhem operation, and partly for general operational reasons, an attempt was made in the autumn of 1944 to perfect the technique of dropping containers from aircraft at 5,000–12,000 feet. The idea was for a small parachute to open at once to steady the flight and for another to open automatically at about 1,000 feet to break the fall. Accurate wind forecasts were needed so that the containers would fall in a given small area.

Details of the investigations made by the meteorological office, No. 38 Group, in late 1944 and early 1945, in connection with the experiments on dropping containers from the higher levels were given in reports by the Senior Meteorological Officer who had the use of a radar wind finding unit at Wittering.[3]

[1] A.M. File S.102245. [2] A.S./304/M.O.8. [3] A.M. File A.758778/45.

Although a technique was finally evolved whereby non-meteorological observers on the ground could set markers according to a standard drift table, and aircraft, already advised of the forecast upper winds, could successfully aim the containers at the dropping zone, it never proved necessary to try the method in actual operations.

Other Special Operations

The first operational flights of No. 38 Group to Norway were made early in November 1944 when agents and supplies were dropped at pre-arranged places ; to co-ordinate the meteorological advice for these flights, consultations took place between the forecasters at No. 38 Group and those at the Type 2 office at Tempsford. These special type of operations continued until the end of the war, No. 38 Group extending its activities to parts of Germany at the end of February 1945, to Denmark in March 1945 and to Czechoslovakia at the beginning of May. Some were fairly large scale operations which depended for their success on detailed accuracy by the forecasters. Moreover, it was decided to try operations over Norway in the non-moon period with aircraft not coming below 3,000 feet, so as to avoid high ground, and to drop containers with delayed action fuses so that the parachute opened at 1,000 feet. This necessitated very accurate wind forecasts for the target areas.

Bastogne

While the normal No. 38 Group operations were proceeding, F.A.A.A. H.Q. were arranging towards the end of 1944 for supplies to be dropped to troops in the Belgium, Luxembourg and Ardennes battle areas ; in particular, many re-supply flights were made to the Airborne Division in the Bastogne area on 24–28 December. Forecasters from the R.A.F. and American weather sections jointly briefed the Chief Staff Officers, and special outlooks, originated jointly by the officers, were issued to F.A.A.A. and to the 9th T.C.C., most of whose planes were now based in France and carried out the required flights. The weather at this period was very foggy and although No. 38 and 46 Group planes stood by from 24 December ready to fly American troops to the Continent to help in the relief of Bastogne, projected flights had to be postponed until 26 December when No. 46 Group took the available troops by air to France.

Tactical Bombing by No. 38 Group

From January 1945, No. 38 Group filled a new role by the tactical bombing of targets near the Western front, the bombing being done by visual or radar methods according to the weather. Very detailed consideration had to be given to the weather on the route, particularly in regard to cloud tops and lanes in cloud layers over the target and in regard to upper winds. It might happen that conditions were unsuitable for normal No. 38 Group operations at a low level but were suitable for the tactical bombing (12,000 feet was about the limiting height), or vice versa, so that the forecasters at the Group had to be prepared to give advice for either type of operation. To facilitate this, it was decided, as a routine, to construct upper air charts at No. 38 Group, the contours being drawn and the temperatures plotted for 700mb. using data supplied by the ETA broadcast. These proved most useful both for wind determination for tactical bombing and for general study by the forecasters.

Preparations for Operation ' Varsity ' (Crossing of the Rhine)

An advanced party of F.A.A.A. moved to Maison La Fittes on the outskirts of Paris in January 1945 and in February it was learned that the whole of F.A.A.A. would soon move to the advanced H.Q. As a result, it was decided that the British meteorological office would go with F.A.A.A. to Paris and it duly moved with its equipment on 26–27 February.

It had been intended that the meteorological staff at F.A.A.A. (Main) should act in an advisory capacity, relaying forecasts agreed by 9th T.C.C. and No. 38 Group,[1] but a large scale exercise, ' Token,' on 16–17 March, involving both British and American Groups, and controlled by F.A.A.A. (Main), showed that the British meteorological staff could not cope with the work. The exercise was the biggest of a series of large scale airborne exercises which took place in March 1945 and was the final rehearsal for operation ' Varsity,' which took place on 24 March. It was therefore decided that the Senior Meteorological Officer, No. 38 Group, should be attached to F.A.A.A. to help with the general meteorological organisation, his deputy remaining in charge at No. 38 Group. Operation Varsity was carried out most satisfactorily on the day arranged in almost perfect weather. At the end of April, when it was clear that no more large scale operations would be required, the British meteorological staff at F.A.A.A. were withdrawn.

Technical Problems

One of the first results of the meteorological work at Ringway was the production of a report in January 1942 on ' The effect of weather conditions on parachuting ' (S.D.T.M. No. 25). A related report, ' Note on the Bumpiness of Aircraft ' (S.D.T.M. No. 37) appeared in October 1942.

When practice glider-tug flights were made in Northern Ireland in 1943, it was soon realised that the glider-tug combination should not enter dense cloud as, unless a glider pilot can see the tug continuously, he cannot take action to avoid sudden jerks on the towrope, which may, therefore, break. Other meteorological factors were summarised in the meteorological section of the Glider Manual and in ' Meteorological factors affecting glider operations ' (S.D.T.M. No. 53) published in July 1943. In order to avoid air sickness of troops carried in the gliders, stable air conditions must be selected and, in this connection, an analysis of ' Meteorological Aspects of Air Sickness in Gliders ' (S.D.T.M. No. 48) was made by the Senior Meteorological Officer, No. 38 Group in May 1943.

To keep the R.A.F. aircrews in full training, operational pamphlet dropping (' Nickel ') flights were made over the Continent at night and various long cross-country ordinary flights were undertaken. At the request of the Operational Research Section (attached to the Airborne Division) which studied the results of these flights, the Senior Meteorological Officer, No. 38 Wing, arranged for photometric measurements to be taken at Netheravon at night in December 1942 and January 1943, to determine the relation of cloud cover to intensity of illumination, an important factor in possible airborne operations over enemy territory. To investigate this matter at close hand, this officer went on an operational ' Nickel ' flight in February 1943, but unfortunately the plane and its occupants were lost. The photometric measurements were discontinued in the same month when 500 readings had been obtained and the analysis of

[1] A.M. File S.102245.

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the results, begun by the Senior Meteorological Officer, No. 38 Wing, was completed by the meteorological staff who had been helping in the work, and was published, in July 1943, as 'The Influence of Meteorological Conditions on Night Illumination' (S.D.T.M. No. 51).

A careful study had been made at Ringway of the anemometer charts in various weather conditions in connection with the problem of forecasting gustiness. The results and conclusions were published in March as 'Forecasting Wind for Parachute Operations' (S.D.T.M. No. 69).

The technical problems related to the dropping of containers was investigated jointly with specialist officers of M.A.P. The meteorological requirements were the mean wind from the point of release to the point where the parachute opens and the mean wind from this point to the ground. By using these two mean winds and an expression given in the papers 'Technical Note No. 857 R.A.E.' and 'T.A.C. Arm. No. 299', the total drift of the container due to the wind effect could be determined, the effect of the speed of the aircraft being allowed for separately. A number of trials were made at Bottisham and, during January 1945, a special Wind Finding Unit (Radar) was formed at Wittering. From February to June 1945, this unit made routine wind observations to 12,000 to 15,000 feet at two-hourly intervals, mainly during the daytime, in conjunction with the special trials, involving the dropping of airborne supplies, being conducted by No. 38 Group. The Senior Meteorological Officer made several reports but the results were not published before the end of the war. In fact, the problem of dropping containers accurately from medium levels was not completely solved. The major remaining difficulty was that of having an observer with a ground party for estimating the lapse rate of temperature (with which the variation of wind at low levels is intimately connected) so as to be able to use the tables for drift, but it was clear that more work was required on the problem.

During August 1944, the operational planning staff at F.A.A.A., Eastcote, requested weather forecasts for periods up to five days as operations were being planned to last up to five days. The forecasts were prepared jointly by the British and American meteorologists at Eastcote who were guided by analogues and by forecast weather maps for the next three days supplied by a facsimile machine from the American Weather H.Q. at Bushy Park who had consultations with the Central Forecasting Office. In view of the limited knowledge of the very intricate mechanism of weather development, it had to be pointed out to the planners that they could not expect such five-day forecasts to be highly or consistently accurate. However, the policy towards the end of the war was to complete airborne operations in one or two days so the difficulty of supplying five-day forecasts was no longer present.

The many requests for climatological and similar reports for the planning of airborne operations were almost entirely dealt with by the special investigations Branch (M.O.9) of the Meteorological Office.

Combined Operations

The supply of meteorological information in connection with combined operations fell naturally into two distinct and easily separable categories, viz. the supply of climatological and technical information to assist the planning staff and the supply of forecasts for actual or intended operations.

Although combined operations had been undertaken before the war, the increasing complexity of the weapons used had fundamentally affected the weather requirements considered suitable for such operations. From the planning aspect, the problem was essentially that of determining the probability of weather which should be simultaneously suitable for all the weapons which it was proposed to use at the time and place selected for the operation. This often resolved itself into determining the probability of the wind, cloud and visibility all satisfying certain conditions simultaneously. Although the frequencies of occurrence of specified values of the individual meteorological elements are tabulated as a matter of routine for a large number of places, it is clearly a practical impossibility to tabulate the frequencies of occurrence of all possible combinations of these values.

The supply of forecasts for impending operations introduced problems of co-ordination. A combined operation often involved the dispatch of units of the force employed from more than one base and normally the ultimate decision to launch the operation depended, in part, on the weather conditions forecast for the relevant period. A forecaster working with the air arm does not normally concern himself with the suitability of the sea for landing operations, and unless he is completely *au fait* with all requirements he may issue a forecast which is completely adequate for one aspect of the operation but which apparently does not correspond with a forecast issued by another forecaster who considers only some different aspects of the operation. This difficulty can only be overcome by ensuring that, when two or more forecasters are concerned owing to units of the force setting out from different bases, the various forecasters shall have opportunity of consulting together before issuing the forecast and that each forecaster shall be familiar with the broad plan of the operation.

Meteorological information in connection with combined operations was first requested on 5 February 1942 when the Senior Meteorological Officer at G.H.Q. Home Forces attended a meeting at C.O.H.Q. to advice on the meteorological aspect of the use of smoke screens during raids on enemy coasts. Subsequently, a brief report was submitted to the Combined Operations Chemical Warfare Sub-committee emphasising the meteorological organisation required in connection with the planning and execution of combined operations. Directives were then issued by the War Office and Air Ministry to Cs.-in-C. and A.Os.C. respectively instructing them to give to the appropriate meteorological officers all information regarding impending combined operations necessary to permit them to co-ordinate their meteorological advice.[1] The Meteorological Office had already issued to Senior Meteorological Officers an instruction regarding the co-ordination of meteorological advice for such operations.[2] A Meteorological Office liaison officer was appointed to Combined Operations H.Q. on 27 February 1942 and a liaison officer from the Naval Meteorological Service was attached to that H.Q. at about the same time. Co-ordination between the two meteorological services was effected through these two liaison officers.

Until D-Day planning began, no special meteorological organisation was needed for combined operations other than the liaison and co-ordinating machinery indicated above, and this remained unchanged in essentials until a special meteorological organisation was set up to advise S.H.A.E.F. The facilities available at the various Meteorological Office outstations and at H.Q. were, of course, used as occasion required.

[1] A.M. File S.77853.
[2] A.M. File S.79076.

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The Supply of Technical and Climatological Information

One of the normal duties of the Meteorological Office is to prepare reports upon the meteorology of specified areas or routes for the benefit of aviation, and a large number of such reports, dealing with areas all over the world, were supplied as a routine to C.O.H.Q., particularly during the first half of 1942, to assist the planning staff.[1] A number of requests were also made for information which involved special analysis of the available climatological information. Some of these could be answered easily and quickly, but others involved much work and included requests for information concerning :—

(*a*) The frequency of snow cover in various parts of Europe (April 1942).

(*b*) The frequency of occurrence along the south and east coasts of England of conditions suitable for invasion of this country. For this purpose, conditions considered suitable for the use of smoke, of gas and for the landing of troops from small craft and from aircraft were defined and each case was treated separately (April 1942).

(*c*) The frequency of poor visibility and light winds at various places on the north coast of Europe between Helder and Brest (August 1942).

(*d*) Probability of weather conditions being suitable in late October and early November for a raid on the north western part of Cherbourg Peninsular (September 1942).

(*e*) The frequency of occurrence of certain specified combinations of wind, visibility and cloud on the Norwegian coast (September 1942).

(*f*) The frequency of occurrence of ' quiet conditions ' on the European coast from Helder to the southern part of the Bay of Biscay (November 1942).

Actual or Projected Combined Operations involving Special Forecast Services

The first combined operation for which special forecasts were arranged was a large-scale smoke generator trial on the River Dee in North Wales in April 1942. This trial was carried out in order to assist in reaching a decision as to the most suitable form of generator for screening landings on a hostile coast. The first combined operation against the enemy for which forecasts were required was the Dieppe raid of 19 August 1942. In that case, however, the Air H.Q. for the raid was at H.Q. No. 11 Group where there was a Type 1 forecast office, so that very little was needed in the way of special arrangements.[2]

The next operation for which special arrangements were made was Operation ' Pullover ' in February 1943. This involved an aircraft proceeding from Wick in Scotland to Lake Alte in Norway. A forecaster was posted to Kinloss for this operation and arrangements were made to obtain special reports of snow cover at Lake Alte. Special forecasts were also issued from the Central Forecasting Office. This operation was eventually cancelled.

Another operation, ' Gunhouse ', was planned for approximately the same period as ' Pullover '. It involved a flying boat proceeding from Sullom Voe to Revsbotten (N. Norway) and thence on to Russia. For this operation, special snow cover reports were obtained from Revsbotten fjord and special forecasts were issued from the Central Forecasting Office to assist the meteorological officer at the base at Sullom Voe. This operation was eventually cancelled.

The biggest combined operation, viz. the landings on the Normandy Coast in 1944, are dealt with elsewhere.

[1] A.M. File S.79668. [2] A.M. File S.79076.

CHAPTER 13

NORTH-WEST EUROPE

As stated in Chapter 1, representatives of the War Office and the Air Ministry, including the Meteorological Office, had formulated plans in May 1936 for supplying meteorological data to the Army and Air Force in the Field in the event of war. These plans, which envisaged the provision of a number of forecasting sections, meteorological sections with sound ranging units and some mobile meteorological units as part of an Expeditionary Force, were later somewhat modified and the provision of meteorological facilities for the Army had not been finally agreed when war broke out.[1] The communications needs of the meteorological sections of the Expeditionary Force had been agreed and were based on teleprinter communication to the Central Forecasting Office, the use of Service signals facilities and wireless receiving trailers for H.Q. R.A.F. Component Field Force and H.Q. Advanced Air Striking Force (A.A.S.F.). Adequate arrangements had been made for the supply of equipment, but transport facilities were still being discussed in September 1939.

Mobilisation

Only a few meteorological personnel could be mobilised on the outbreak of war and it was impossible to send overseas enough officers and other ranks to meet the needs of the Army and Air Force in the Field. Some reinforcements were sent out in December 1939, but by the end of 1939, the staff available in France were still inadequate.

The first meteorological contingent set up in France was at H.Q. A.A.S.F. at Rheims. The Chief Meteorological Officer arrived on 3 September and two more officers and ten other ranks arrived during the following fortnight. A liaison officer from the Meteorological Office had been posted to the H.Q. of the Office Nationale Meteorologique (O.N.M.) in Paris, and the Chief Meteorological Officer, A.A.S.F., at once contacted him to arrange for the supply of basic data. None were forthcoming at first, and forecasts had to be based on local observations only and on advisory forecasts supplied by O.N.M. and H.Q. Bomber Command. Unsuccessful attempts were made to get information by telephone from the O.N.M. and from 8 September data were obtained by dispatch rider from a neighbouring O.N.M. office. On 13 September, a teleprinter link was set up with O.N.M. and, after overcoming preliminary troubles, the under-staffed forecast section, which had started to work on 7 September, was soon fully functioning. In due course, the meteorological section of H.Q. A.A.S.F. was not only serving Air Staff at H.Q. and the various units of A.A.S.F. but helping the meteorological section which had arrived at H.Q. R.A.F. Component of the Expeditionary Force at Marveil, near Arras. The units of R.A.F. Component were also served by the forecasters at H.Q. A.A.S.F. through the meteorological section at Marveil. The meteorological section at H.Q. A.A.S.F. began full observations on 28 September.

[1] A.M. File S.37349/I.

Staff for the meteorological section at H.Q. R.A.F. Component, B.E.F., began to arrive on 13 September. The section had been formed late in August at South Farnborough and began to operate at the beginning of October. The signals facilities provided at first were W/T only with standard R.A.F. receivers R.1084, and it was impossible to obtain enough data for reliable forecasting. The partial use of operational teleprinter circuits was almost useless as data thus obtained were both scanty and much delayed. No teleprinter line to ETA was installed until 14 November, although a full 24-hour forecasting service had to be started before then. The Officer Commanding the Meteorological Service in the Field arrived at H.Q. R.A.F. Component on 2 November.

The only meteorological personnel who could be provided at first to work directly with the Army were those who had been allocated to Survey Regiments. The section for No. 1 Survey Regiment went to France with the meteorological personnel for H.Q., R.A.F. Component but the contingent for No. 2 Survey Regiment did not report for duty until early November.

The Air Ministry asked the War Office on 14 September to agree to the postponement for two or three months of the provision of forecasting units to each of the two Corps H.Q. which formed part of the Army organisation in the Field. The War Office agreed but said that they regarded the supply of the units as a matter of the first importance and asked that, if possible, they should be made available sooner. War Office and Meteorological Office representatives discussed on 12 October the Army's meteorological needs and agreed that Army G.H.Q. would not need a separate meteorological section as telephone communication with H.Q. Air Component would probably suffice and that one meteorological section could serve both Corps H.Q. and Wing H.Q. as these would always be near each other.

The Director of the Meteorological Office visited A.H.Q. and G.H.Q. of the Field Force, H.Q., A.A.S.F. amd the H.Q. of the French Meteorological Service early in October 1939 to discover what reorganisation of the meteorological service for the Army and R.A.F. would be needed in the near future. The first action to be taken on his report was the appointment of the Officer Commanding the Meteorological Service in the Field with the new title of Meteorological Officer-in-Chief. After D.M.O.'s visit to France, a scheme of meteorological communications was drawn up in early November and included :—

(*a*) A direct teleprinter line from ETA to H.Q. Air Component.[1]

(*b*) A direct teleprinter line from H.Q. Air Component to H.Q., A.A.S.F.

(*c*) A direct teleprinter line from H.Q., A.A.S.F. to the O.N.M.

(*d*) A direct teleprinter line from H.Q. Air Component to Calais, the nearest regional communication centre of the O.N.M.

(*e*) Direct teleprinter lines from H.Q. Air Component to the various Wing H.Q. of the Air Component.

The Static Period up to April 1940

The Royal Air Force.—A new Command, British Air Forces in France (B.A.F.F.) was formed on 15 January 1940 to co-ordinate the operation of all Air Force units in France. It absorbed the Air Component of the B.E.F. and

[1] With switching device so that both H.Q.s could receive data from ETA simultaneously.

its scope included the A.A.S.F. with Bomber Squadrons detached from Bomber Command. As a result of this new formation and of a visit by the U.S. of S. and A.C.A.S. to France in January, the Meteorological Officer-in-Chief was transferred in March 1940 from H.Q. Air Component to H.Q. B.A.F.F., to advise the A.O.C.-in-C. in connections with operations.

It had been arranged in December 1940 for routine forecasts, varied as to area and contents to meet the needs of individual units, to be provided to all units several times daily. Warnings of dangerous phenomena were issued as required.[1] These arrangements, with minor modifications, continued throughout the period. Special forecasts were issued for operational flights including survey photography and long distance reconnaissance flights over Western Germany by No. 70 Wing. At the end of January, it was arranged for forecasts and warnings to be provided to the Balloon Squadrons at defended points and for a small meteorological detachment with adequate communications to be set up with each squadron to provide detailed information and advice.

A syllabus of meteorological instruction was prepared and selected officers lectured to the aircrew of the various squadrons. With the transfer of the Meteorological Officer-in-Chief to H.Q., B.A.F.F., the Chief Meteorological Officer, H.Q. Air Component, became responsible for all meteorological detachments in the B.E.F. area and for meeting the requirements of the General Staff at G.H.Q. as well as Air Staff at H.Q. Air Component. The Chief Meteorological Officer at H.Q., A.A.S.F., continued to meet the requirements of H.Q., A.A.S.F. and associated formations and units. Routine forecasts and warnings were issued to all concerned and special forecasts supplied for particular flights and operations including some over South and Central Germany by detachments of No. 4 Group Bomber Command.

It was arranged in February 1940 for meteorological detachments to be provided at Regional Control Stations in the B.E.F. and A.A.S.F. areas.

A meteorological officer was attached to No. 1 Mobile Balloon Unit near Nancy and obtained advice from the meteorological section of H.Q., A.A.S.F.

The Army.—At a discussion, at H.Q. Air Component, with officers from G.H.Q., early in February 1940, on the meteorological needs of the Army, it was considered that it would be impracticable for meteorological sections attached to Wing H.Q. of the Air Component to serve Army formations also but that a meteorological section should be set up with each Army H.Q. to provide detailed advice to the Army Commander and General Staff in regard to operational requirements. It was also considered that a Meteorological officer should be attached to each Corps H.Q. for advisory purposes. It was envisaged that communications would be needed between the Army Meteorological Sections and the forecasting centre at H.Q. Air Component ; not only would the meteorological units with Artillery formations and Survey Regiments need to be mobile but all meteorological sections with the Army should be provided with adequate transport facilities. A statement of the requirements was submitted to G.H.Q. for representation to the War Office. The Army Branch (M.O. 8) of the Meteorological Office discussed the question with the War Office and agreement was eventually reached, but its implementation could not be effected before the withdrawal from France.

[1] A.M. File S.58740.

Meanwhile, the meteorological section of H.Q. Air Component supplied meteorological information to G.H.Q. I and II Corps. Mobile meteorological units were provided for the supply of Meteor reports to certain artillery formations in the Boulogne and Nantes areas while other formations were issued with such reports from the meteorological sections of H.Q. Air Component or H.Q., A.A.S.F.

Meteorological detachments with the 1st and 2nd Survey Regiments continued to meet the needs of these units and a third detachment with the 3rd Survey Regiment proceeded to France in April. Although these detachments were allocated to the Army, they were not formally established as Army units.

Communications.—Little progress was made towards developing a satisfactory scheme of meteorological communications as planned in November 1938.[1] The teleprinter line from H.Q. Air Component and the O.N.M. operated from 24 January and that between H.Q. Air Component and H.Q., A.A.S.F. from 11 February. A switch at H.Q. Air Component enabled data from ETA to be received simultaneously at both H.Q.s but the lack of two-way communication made it difficult to ensure that reception at H.Q., A.A.S.F. was being maintained satisfactorily. In one case, the teleprinter was out of action for eight days owing to a fault at the A.A.S.F. end. The teleprinters at H.Q. Air Component were linked to the ETA and O.N.M. broadcasting systems and schedules of essential data were prepared for use in the event of its being found more satisfactory to arrange special transmission on either or both of those systems for the Meteorological Service in the Field.

The Director of the Meteorological Office called a meeting on 2 January on meteorological communications. It was attended by the Meteorological Officer-in-Chief and representatives of the War Office, Air Ministry (Directorate of Signals) and 1st and 2nd Air Formation Signals, B.E.F. The subjects discussed included probable new requirements in the field, the procedure for requisitioning new teleprinter lines, the provision and technical details of instruments and equipment. Subsequently, requisitions were made for new lines between H.Q. Air Component and H.Q., B.A.F.F.; H.Q., B.A.F.F. and H.Q., A.A.S.F.; H.Q., A.A.S.F. and 4 Wing H.Q.; H.Q. Air Component and Le Havre; H.Q. Air Component and H.Q., A.A.S.F. and the respective Regional Control Stations. The complete scheme could not be implemented, however, owing to the non-existence of teleprinter terminal units, batteries and the necessary operating and maintenance staffs. The development of meteorological services in the Field was thus severely handicapped.

Towards the end of April, special meteorological W/T sections were being formed in B.A.F.F. (from resources within the Command) for reception of meteorological broadcasts in the event of a general land-line failure, and plans were made to set up similar sections at Wing H.Q., Army and Corps H.Q. and at Balloon squadrons so that forecasting detachments could function independently.

Observations.—Full surface observations, at synoptic and intermediate hours, were maintained throughout the period at H.Q. Air Component and H.Q., A.A.S.F. Regular pilot balloon ascents were also made at both H.Q. The two detachments with Survey Regiments and the two detachments with

[1] A.M. File S.43281.

A.A. units also made regular observations. In the former case, the observations were interrupted during temporary moves of the S.R. Batteries and during exercises when full time had to be devoted to the special observations needed for sound ranging.

Observations from H.Q. Air Component were transmitted regularly to ETA from 12 January while those from the detachments with A.A. units were transmitted to Paris via the appropriate French Regional Station and were included in the Paris broadcasts.

From 1 January, meteorological observations in an abbreviated code were sent to H.Q. Air Component from all R.A.F. airfields in the B.E.F. area at 0800, 1100 and 1400 hours G.M.T. together with intermediate reports of sudden weather changes. Similar arrangements were made in the A.A.S.F. area in February, Wing H.Q. sending reports at 0800 and 1400 hours daily.

The Mobile Period and Evacuation

At the beginning of the German offensive early in May 1940, the disposition of the meteorological sections was :—

(*a*) At H.Q., B.A.F.F., an administrative centre with a climatological section.

(*b*) At H.Q., B.A.F.F. (North), a mobile forecasting section without W/T facilities.

(*c*) At H.Q., R.A.F. Component, a static forecasting and administrative centre controlling sections with Nos. 912, 924 Balloon Squadrons, the Sound Ranging Sections with Survey Regiments and detachments at some airfields for work with Regional Control Stations.

(*d*) At H.Q., A.A.S.F., a static forecasting and administrative centre with a few small detachments at airfields.

Apart from the mobile meteorological sections which had been provided for certain artillery formations in the Boulogne and Nantes areas, the agreed plans for a comprehensive organisation for Army formations had not been implemented.

The meteorological service for land and air forces worked as smoothly as could be expected until the German break-through caused H.Q., R.A.F. Component to be withdrawn from Arras to Folkestone via Boulogne. Meteorological teleprinters were working between the H.Q. and both Paris and England up to the moment of withdrawal, but only a small operational H.Q. remained active in France thereafter and there was no possibility of providing a meteorological service. The sound ranging sections evacuated with their Survey Regiments through Dunkirk after very active operations. The section with No. 912 (Balloon) squadron at Boulogne remained in active operation until the port was evacuated.

Meanwhile, the forces to the south of the German thrust to the channel coast were reorganised; Meteorological H.Q. remained with H.Q., B.A.F.F., which had moved back to Orleans, and H.Q., A.A.S.F. with its meteorological section was withdrawn from Rheims to new H.Q. Replanning proceeded rapidly, a new meteorological section (complete with W/T vehicle and Office Trailer) was quickly formed at H.Q., B.A.F.F. with personnel flown from England, and moved independently by road to the south of France to serve No. 71 Wing,

set up for bombing operations against Italy. This section arrived on 7 June and saw a few days of operations before withdrawal, via Marseilles and Gibraltar, after the French capitulation.

Very close collaboration had been maintained with the French Meteorological Service, which had been militarised on the outbreak of war. A liaison officer from the Meteorological Office had been sent at the beginning of the war to the H.Q. of the O.N.M. in Paris and there was a series of Franco-British meteorological war conferences for discussion of questions of mutual interest, particularly concerning communications.

Norway (April 1940–June 1940)

The Air Component of the North West Expeditionary Force (N.W.E.F.), known as Force X, was formed in April 1940 at Uxbridge. Its personnel and equipment sailed from Leith for Norway on 7 May 1940 and, a few days later, they reached Harstad, on the largest of the Lofoten Islands, about 30 miles from Narvik. The H.Q. was at once set up at Harstad near the British Army G.H.Q. At first, personnel and equipment were kept to the minimum and the meteorological section consisted of an officer and two corporals with a small packing case of meteorological equipment including a sling parchrometer, aneroid barometer, prismatic compass and thermometers.[1]

It was the duty of the meteorological unit to provide meteorological data to the N.W.E.F. in general and to the R.A.F. in particular, and to supply synoptic weather reports from the N.W.E.F. area to the Meteorological Office. It was proposed to set up a 24-hour forecasting section at the H.Q., Air Component, and later at each airfield as these became available. It had been arranged before embarkation, for further personnel to follow soon afterwards to set up the forecasting section at H.Q., but these personnel did not arrive until after it had been decided in June 1940 to withdraw the N.W.E.F., and they returned to the United Kingdom without disembarking.

Soon after Force X had arrived in Norway, the Air Ministry were asked for additional staff and equipment for two additional meteorological offices for two airfields, Bardofoss and Skaanland, which were nearing completion. In this case, also, it had been decided to evacuate before the personnel arrived.

The forecasts received from the Meteorological Institute at Tromso, and such single observer forecasting as could be done, constituted the only forecasting service that could be provided. Attempts were made to prepare rough synpotic charts using synoptic reports from the Tromso area and from a Naval vessel in the Narvik area, but the results were of little use for forecasting.

Technical difficulties prevented the reception of the synoptic transmissions from Air Ministry, and the arrangements made before embarkation for receiving meteorological data from Air Ministry were never put into effect.[2] Some forecasts were passed to a number of Army and Navy units in the area, but it was not possible to prepare Meteor reports, although preparations were made for the supply of upper air data by aircraft ascents.

A climatological report on North Norway, based on data available at the Meteorological Office, was prepared before the departure for Norway, and was circulated to a large number of units of all three Services in the area.

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[1] A.M. File S.61564.

[2] A.M. File S.61594.

At first, weather reports were sent to the United Kingdom by broadcasting them thrice daily from Tromso in meteorological cypher, and relaying them to the United Kingdom by the wireless station at Bodo. When bombing put the Bodo W/T transmitter out of action, the messages were telephoned from Tromso to the Naval Signals Office at Harstad, and thence relayed to the Admiralty; later, the Tromso-Harstad link was by W/T. At first, the messages consisted of synoptic reports for Tromso and a few stations in North Norway. When the messages were passed through Harstad, the Harstad synoptic report was included. On receipt in the United Kingdom, the messages were at once passed to ETA.

To meet the forecasting needs of the squadrons and other units of the N.W.E.F., the aid of the Meteorological Institute was enlisted. The Institute was still functioning, but under considerable difficulties, as it had access only to Norwegian reports which became scarcer as the German occupation progressed. A R.N.V.R. meteorological officer, who was stationed there, held the British cyphers, and it was arranged for him to pass to the meteorological office at Harstad two encyphered forecasts daily for the Harstad and Narvik areas, using civil lines for the purpose.

CHAPTER 14

S.H.A.E.F., A.E.A.F., 21st ARMY GROUP AND 2nd T.A.F.

Supreme Headquarters, Allied Expeditionary Force[1]

Formation of Meteorological Section at Command H.Q.

It was agreed late in 1943 that a meteorological section should be formed at the Supreme Allied Command H.Q., under an officer of the Meteorological Office, who was to have as a deputy a Colonel from the United States Army Weather Service. The Section was formed on 1 January 1944 in the Operations Branch of Supreme H.Q., immediately under, and responsible to, the Assistant Chief of Staff G–3. No forecasting section was set up at SHAEF itself then or later, primarily because it was known that Supreme H.Q. would be located near the Central Forecasting Station of the U.S. Army Weather Service until after D Day.

The Chief of Staff laid down that the Section should provide meteorological advice to the Supreme Commander and his Staff, co-ordinate at the highest level the meteorological arrangements made by the naval, army and air forces of the United States and Great Britain under the Supreme Commander, and co-ordinate the meteorological advice provided by the American and British meteorological officers on the Staffs of the Naval, Army and Air Commanders-in-Chief.

Planning Advice for Neptune

As the planners had already been at work for most of 1943 on the broad lines of OVERLORD (the entire operation of invasion and the early stages in the recovery of continental territory) and NEPTUNE (the assault and landings), the first tasks were :—

(*a*) To obtain as much information as necessary about the provisional operations plans.

(*b*) To arrange for the naval, army and air planning staffs to set down the minimum requirements in weather conditions deemed necessary for their particular aspects of the operation in its various stages.

(*c*) To obtain meteorological information about the likelihood of specified weather conditions in locations and at the times laid down in the plans.

(*d*) To interpret this meteorological information to the planning staffs, particularly in the light of changes which were made in the provisional operational plans from time to time.

It was never practicable to get the various Staffs to agree on one set of weather requirements which all could accept as the minimum conditions in which the operation could be carried out, as many different kinds of operation, each requiring its own particular conditions were involved, and the necessary conditions changed almost hourly with the phase of the operation. From the

[1] A.M. File S.97240.

air aspect alone, cloud conditions suitable for the landing of airborne forces at HH–X hours would not give heavy bombers their best opportunities at HH–Y hours, and these in turn would not be the best for medium and light bombers operating at lower levels on small targets at HH–Z hours : fighter aircraft required cloud and visibility conditions considered unnecessary for troop-carrying or bomber aircraft. Probably the only firm restrictions were those imposed by the naval authorities on the strength and, to a less extent, the direction of the surface wind in the hours just before the operation, with their immediate effects on the state of sea for the crossing and the beach conditions for the initial landings. But as the local conditions of sea and swell would be affected by winds up to hundreds of miles away, the likelihood of strong winds in the Atlantic also entered seriously into the considerations.

Visibility, an important factor for all three Services, had to be good enough to let the various types of aircraft take off from, and assemble over, their English bases, and to see their targets in and behind the assault area : visibility at sea had to be adequate to allow the multitude of craft involved to keep their proper station and also allow the naval bombarding forces to see their targets on land : in close bombardment, the aircraft spotting for the naval bombarding forces required visibility adequate for directing that force on to its land or sea targets.

There were other factors. For example, the condition of the ground in the operational area as regards softness for the movement of heavy vehicles both tracked and untracked. This factor was considered in the planning stages, but in certain circumstances it might also have been important in deciding the day of assault. Of a more detailed nature, but in certain contingencies by no means unimportant were the actual conditions as regards vertical temperature structure in the atmosphere and wind speed and direction along the coastline immediately after HH hour, as these conditions determine the behaviour of smoke screens.

As it turned out to be impracticable to satisfy the conflicting claims of all planning staffs at all phases, the Meteorological Section adopted its own list of minimum requirements and this list was not openly disavowed.

In English weather, it was clearly impracticable to set up an ideal set of conditions even if such were possible and defer the assault until this set of conditions was obtained. In the summers of some years they would not be obtained within any predetermined period of a month or even two months. Moreover, other factors apart from the purely military and political, were at least as important in determining the period within which the assault must be effected. These include the times of high and low tides, and the intensity of ground illumination as affected by twilight and the phase and altitude of the moon. It was, therefore, necessary to define a set of minimum meteorological conditions which could be accepted by all arms as being the worst conditions in which the operation could be launched. Such a set of minimum conditions was never wholly accepted by all the forces, but the Meteorological Section, SHAEF, kept the following conditions in mind :—

Naval Requirements

(*a*) Surface winds should not exceed Force 3 (8–12 m.p.h.) on shore or Force 4 (13–18 m.p.h.) off shore in the assault area during the days D to D plus 2. Winds might be Force 5 in the open sea, but only for limited periods.

(*b*) In the days preceding D Day, there should be no prolonged periods of high winds of such direction and in such Atlantic areas as to produce any substantial swell in the Channel.

(*c*) Visibility not less than three miles.

Air Force Requirements

(*a*) Airborne transport (HH–6 to HH–4) : cloud ceiling at least 2,500 feet along the route to and over the target area, visibility at least 3 miles.

(*b*) Heavy Bombers (HH–4 to HH) : not more than 5/10 cloud cover below 5,000 feet and cloud ceiling not lower than 11,000 feet over the target area.

(*c*) Medium and Fighter Bombers (HH–2 onwards) : cloud ceiling not less than 4,500 feet, visibility not less than 3 miles over the target area.

(*d*) Fighter and Fighter Bombers (HH–18 onwards) : cloud base not less than 1,000 feet.

(*e*) Base areas : cloud not below 1,000 feet and visibility not below 1 mile except for heavy bombers, for which there was the additional stipulation that low cloud tops must be less than 5,000 feet high and there should be only fragmentary middle cloud.

Army Requirements

(*a*) Landings of Airborne Troops : for paratroops, the surface wind over the target area should not exceed 20 m.p.h. in the target area and should not be gusty ; and for gliders the surface wind should not exceed 30–35 m.p.h. The intensity of the ground illuminations should not be less than half moon at 30° altitude or the equivalent in diffuse twilight.

(*b*) Ground Forces : the ground should be sufficiently dry to allow movement of heavy vehicles off made-up roads.

From British sources alone, at least four sets of meteorological statistics, more or less independently derived, had been supplied to the Operational Planning Staffs before the formation of the Meteorological Section, one set to the Naval Staffs by the Naval Meteorological Service, one to the Army planners and two co-ordinated sets from the Meteorological Office to the Air Staffs. The U.S. Army Weather Service had also provided information. It had probably never been intended that those sets of information should confront each other on a planners' conference table in the hands of men unskilled in interpreting masses of meteorological statistics : but they had been so used and the result was bewilderment. It therefore became an important and urgent task to co-ordinate the various meteorological studies, to interpret them in the light of latest plans and statements of minimum requirements, and to ensure that the joint planning staffs were provided with a single, comprehensive body of meteorological advice presented in an understandable form. This was done by preparing diagrams and statements and by frequent personal presentation at the planning conferences. At this stage, in the latter part of January and February 1944, when rather large modifications were introduced into the operational plans by military circumstances, revised interpretations of the meteorological advice had to be available immediately.[1]

[1] *See* Appendix No. 9 for a summary of a statistical examination of the probability of obtaining most of the conditions mentioned in the preceding section on any one day or sequence of days.

During the same phase, plans for the various RANKIN operations (A, B and C) also needed much meteorological advice and interpretation, the basic information for which was derived partly from U.S. Army Weather Service sources and partly from the Investigations Branch, Meteorological Office.

Forecast Information

The other main class of meteorological information needed by the Supreme Commander's Staff included forecasts of weather conditions for sets of days as far ahead as possible from the day of issue. For NEPTUNE, the Supreme Commander would need to issue his orders for the first movements of his Forces about a week before the landing day, and the immediate follow-up phase after the first landings would need a maximum of two to three days of reasonable weather after the initial assault.

From the outset, the Supreme Commander and his senior staff were anxious to test the value of the help which the Meteorological Section was likely to give in making the decision for the assault and in February, the Section was instructed to provide long range forecasts at regular intervals. These were provided by means of conferences using privacy telephone facilities (scrambler) arranged with the Central Offices of the Meteorological Office, U.S. Army Weather Service and the Naval Meteorological Service of the Admiralty as the main participants ; the Staff Meteorological Officers of the Naval and Air Commanders-in-Chief also took part with special interest in the operational implications of the conference so far as concerned their particular spheres. Army interests were looked after by the representative of the Air C.-in-C. The Chief Meteorological Officer, SHAEF, or his deputy, was chairman of all conferences.

The forecasts of state of sea and swell were provided by the British Naval Meteorological Service which had made a special study of sea and swell and their relationships with the nature and direction of the beaches, and the local and distant (Atlantic) wind regime. The Central Forecasting Offices agreed on the wind direction and speed for each day and with these forecasts of wind, the specialist section of the Admiralty Forecasting Centre worked out the likely sea and swell conditions.

At first, the forecasts were issued each Monday morning and an attempt was made to forecast the weather in Southern England and the English Channel for the rest of the week, amendments being issued as necessary. This procedure was soon made more specific by issuing each day, regarded as day n minus 3, a forecast for the set of days n minus 2 to n plus 2. This in turn was supplemented by arranging specially to notify the Supreme Commander on any day n minus 3 when the weather conditions over the set of days n minus 2 to n plus 2 were forecast to fall within the minimum requirements for NEPTUNE. A fourth stage was reached when, from April onwards, the Chief Meteorological Officer was instructed to present personally at the Supreme Commander's regular weekly meeting each Monday, a forecast for the following Thursday, considered as a dummy D Day, and for the immediately preceding and following days. The Supreme Commander and his various Force Commanders at the meetings questioned the Chief Meteorological Officer about the suitability of the weather for that part of the operation for which each was responsible. The meeting then decided whether or not the Supreme Commander should issue his orders for

NEPTUNE to proceed on that particular Thursday. On each following Monday an inquest was held on the decision taken and on the meteorological advice on which it was based. As well as providing opportunities for the Supreme Commander and his Force Commanders to become acquainted with the limitations of forecasting and to assess the reliability of the advice supplied, the arrangement was an exercise for the Commanders themselves in making the final decisions, taking into account the different and conflicting weather requirements of the Forces involved.

In the final stage of this aspect of the Section's work, the Chief Meteorological Officer and his deputy were transferred on 28 May to the Supreme Commander's Advanced H.Q. and attended all meetings leading to the final decisions for the assault. In the four or five days immediately preceding the launching of the operation, the Supreme Commander and his Chiefs of Staff, with the Force Commanders and their Chiefs of Staff, met several times daily expressly to hear and discuss the latest meteorological information about likely conditions in the Channel, along the Normandy coast and in English airfield areas.

In addition to the procedures outlined above, all of which were designed for the Supreme Commander's D Day decisions, the forecasts issued by the Meteorological Section were used by the Supreme Commander's Staff for deciding on large scale exercises and operations and involving forces under the control of SHAEF.

During the weeks preceding the scheduled day for the NEPTUNE assault, the number of meteorological conferences with the Central Forecasting Offices (C.F.O.s) was increased from one or two as in the early months to three or more each day, viz. :—

(*a*) A preliminary conference in the late afternoon (1730 hours) to allow the C.F.O.s to discuss the lines on which they were thinking about synoptic developments over the next five days.

(*b*) A main conference in the late evening (2100 hours) at which the terms of a 5-day forecast, to be agreed or accepted by all concerned were discussed, and

(*c*) A morning conference (varying in time from 0630 to 0830 hours) at which any necessary modifications in the operational part of the previous evening's 5-day forecast were discussed and amendments issued if required.

(*d*) On the days immediately preceding D Day, a further conference was held at 0300 hours each morning on which was based the final advice to be presented to the Supreme Commander's meeting at 0415 hours.

Each of the conferences usually lasted about one hour, but sometimes extended to two hours, particulaly the evening conferences preceding D Day.

Co-ordination of the Meteorological Arrangements for the Forces under the Supreme Commander's Control

For operation NEPTUNE, each of the Force Commanders under the Supreme Commander had his own meteorological service and adviser : United States and British naval, army and air meteorological services all more or less independent of each other, were involved. In addition to the supply of information to the Supreme Commander and his Staff, one of the main

functions of the Meteorological Section SHAEF was to co-ordinate the arrangements among these several meteorological services. This had two aspects: the co-ordination of the meteorological advice given to the various Force Commanders, and the co-ordination of the arrangements in the field.

The paramount importance of the first of these two aspects arises from the following considerations. As soon as an operational decision is made for a complex operation, instructions are issued by the Supreme Commander to the various Force Commanders to proceed with the execution of their parts of the whole operation. It is therefore highly important to ensure that the meteorological advice given to the separate Commanders does not conflict with the advice on which the primary decision is made. This necessitates each of the meteorological staff officers and their principal forecasting offices in the field being provided with a statement of the forecast on which the advice to the Supreme Commander has been based, and the advice given to the operational units right down the chain of command should also be based on this statement. This in turn, makes two big demands on the statement of the forecast which has to be agreed by the representatives of the principal meteorological services involved and has to be framed in terms which can be used operationally by very diverse kinds of forces interested in different aspects of the weather conditions.

To achieve some kind of agreement with representatives of different forecasting Centres about a broad description of future weather to be conveyed orally to a Commander and in which aspects essential for the Commander's decision can be stressed and others not so essential can be minimised, is one matter, but it is quite another matter to commit such advice to paper for promulgation and use down the chain of command of specialised operational formations of different Allied Forces. To be of use for this purpose, the statement needs accurate definition of the timing of weather sequences, the intensity of the accompanying weather, the specific localities affected, etc.; and to achieve agreement by a number of independent forecasting centres on a detailed statement of this kind almost invariably requires that the advice from only one of the Centres must be taken, or that the statement must be so worded for acceptance by all the Centres as to be of little real value to the meteorological advisers at operational formations. Which one of these courses, or a compromise variant of them, is to be taken depends on a range of factors, chief among which clearly is the importance of the occasion, *i.e.*, the proximity to the 'final and irrevocable' decision. This was unquestionably the most difficult and troublesome of all aspects of the Meteorological Section's work. For the Chief Meteorological Officer to decide about the advice he would give the Supreme Commander was normally easy, but the guiding of the conference and the forming of the statements to be issued to the various Services involved was quite another matter.

That it proved to be practicable to issue statements each day from late March till mid-June describing the likely weather events for the next five days was due largely to the abnormally high proportion of quiet and featureless weather conditions during that period. To this could be added the continuous spirit of accommodation and co-operation among the participants of the conference.

From the formation of SHAEF Meteorological Section until after D Day, the Chief Meteorological Officer periodically convened meetings of the

Meteorological Staff Officers of the various operational formations to discuss arrangements for co-ordination of effort in the field. Included among the many matters discussed and agreed upon at those meetings were :—

(*a*) Co-ordination of planning advice and arrangements for ensuring that the advice given on the basis of different statistical analyses by the Meteorological Staff Officers to the various Force Commanders should not conflict with each other or with the advice given to the Supreme Commander.

(*b*) Arrangements for the distribution and use of the five-day forecasts issued by SHAEF Meteorological Section.

(*c*) The issue of sea and swell forecasts by the British Naval Meteorological Service.

(*d*) Arrangements for the collection and distribution of meteorological information in the OVERLORD area of operations.

(*e*) Reporting codes to be used in the field.

(*f*) Index reporting numbers to be used by meteorological sections after landing on the continent and the means of identification of position in reports from mobile stations.

(*g*) Code for wireless transmission of forecasts in the field.

(*h*) Transmission of meteorological information from the OVERLORD area back to the base C.F.Os.

(*i*) Requirements and arrangements for meteorological teleprinter channels to France for U.S. and British Forces.

(*j*) Re-establishment of meteorological services in liberated territories.

(*k*) Forecasting ground surface conditions as regards muddiness (trafficability).

When necessary, the Chief Meteorological Officer, SHAEF, acted as the intermediary with the Directors of the various Meteorological services concerned in obtaining decisions on these matters, and, on the military side, he arranged for instructions to be issued by Supreme H.Q. to the authorities at H.Q. of the Forces Commanders-in-Chief to ensure uniformity of action.

Post D Day Work of the Meteorological Section, Supreme Command H.Q.

After D Day, the SHAEF Operational Staffs continued to ask for forecasts of weather in the Channel and beachhead during the immediate follow-up and build-up phases of the operation, but decisions on particular separate phases were taken increasingly by the Force Commanders and did not require high level co-ordination at Supreme H.Q. The meteorological conferences between the Central Forecasting Offices became simply 'exchange-of-view' conferences there being no obligation on the participants to agree on a forecast for issue to operational formations.

Questions concerned with the operational effectiveness fo the meteorological sections which had already landed in France became urgent, and the U.S. and British meteorological authorities discussed such matters as modification in the means of identifying the positions of mobile stations, the security of meteorological information transmitted from the operational area and modified codes for transmitting weather forecasts by radio from H.Q. Section to the field station units (PREMET code). While the British meteorological authorities

maintained that no sound grounds existed for relaxing security measures even though Allied and enemy formations were operating close to each other, the U.S. Army Weather Service advocated transmitting meteorological reports from OVERLORD area in uncyphered form in the interests of speed and efficiency. The main U.S. and British operational H.Q. were consulted by SHAEF on the matter, and the consensus of opinion was that the NEPTUNE security measures should be continued at least over the first months of the campaign.

By arranging conferences at SHAEF with the appropriate specialists of the Army Groups concerned, the SHAEF Meteorological Section tried during this period to ensure that Army Groups realised the probable value which information on 'trafficability', provided by specialist meteorological officers, might have in the autumn and winter months. The Army specialists on tracked vehicles were indeed convinced of the value of such information, but at that stage in the campaign the various field administrative staffs were impressed with the need to keep down the number of personnel at mobile operational H.Q.

The clauses dealing with enemy meteorological services to be introduced into the Supreme Commander's draft Armistice terms had already been discussed between the Chief Meteorological Office SHAEF and the Directors of the British and U.S. Meteorological Services. Immediately the invasion was launched the consultations were renewed to ensure the safeguarding of allied meteorological requirements.

Because the primary need for co-ordination of meteorological advice at Supreme H.Q. had passed when the NEPTUNE operation and its immediately following phases had been completed, it was decided in July 1944 that the Meteorological Section, in the form in which it had functioned since January, had completed its mission. It was disbanded at the end of July.

The Weather Factor in the D Day Decision

There was considerable difficulty in obtaining a clear synoptic picture of what was happening over the northwest Atlantic at the most crucial time: uncertainties in pressure distribution were such that the Central Forecasting Offices differed from each other by as much as 10 millibars in their interpretation of the pressure in an important area, and even after the event it was not easy to have confidence in any reconstructed synoptic chart.[1]

The critical synoptic developments took place in the area bound approximately 55°–60° N. and 15°–35° W. between the early hours of 2 June and midnight of 4 June. The western part of this area is normally empty of reports and the eastern area was partially covered by one of the regular meteorological reconnaissance flights. Just preceding and during the NEPTUNE operation, a ship reported from the area between 52°–59° N. and 22°–25° W. During the most critical time, 3 June to 4 June, the reports from this single ship became all important, and it was, therefore, unfortunate that just during the most critical hours very considerable uncertainty was introduced in the definition of the situation by a discontinuity of 20 millibars in the pressure reported by the ship. It might appear that the reality or otherwise of so great a discontinuity between pressures reported every three hours in June could readily have been decided upon, but the obscurity from this source at the critical period came at a time when the general activity rose rapidly to a level far above normal even for disturbed conditions. The pressure reading of 976·8 millibars at Wick at 0400 hours on 5 June, the day of the scheduled assault on the French coast, was probably the lowest recorded June reading in the British Isles. Apart from that isolated pressure, a search through synoptic charts showed that there was no situation in the period mid-May to mid-June during the last forty years of similar intensity (two depressions each with centres below 980 mbs. simultaneously in the North Atlantic) and rate of development. The Central Forecasting Officers were, therefore, naturally reluctant to forecast movements of systems across the Atlantic at an average speed of 40 m.p.h., the speed of at least one of the Atlantic depressions during the very critical period.

[1] *See* Appendix No. 10 for the details of the meteorological advice given to the Supreme Commander in the series of conferences which led to the decision for the landings in France on 6 June.

Notwithstanding the above difficulties, the main facts from the meteorologist's point of view were :—

(*a*) that the whole complex operation scheduled for 0630 hours on 5 June was deferred to an unknown date on a day-to-day basis on a weather forecast given 36 hours before;

(*b*) that, as an entirely separate and unexpected decision, the Supreme Commander's 'final and irrevocable' order to proceed with the assault on the morning of 6 June was made on a forecast of weather presented on the evening of 4 June.

It is true that decisions had been taken on 28 and 31 May and 1 June which involved the sailing of naval bombarding forces and the more distant assault Forces, and that those decisions were at least partly influenced by meteorological advice, but it had been made clear that those Forces would not be allowed to sail on the scheduled dates in advance of D Day only if the meteorological advice was that conditions eight days ahead (in the case of the forecast on 28 May, and correspondingly shorter periods for 31 May and 1 June) would be prohibitive for the assault in the Channel area and Normandy coast by reason of continued gales or continuous low cloud. In the circumstances of the weather situation at the time, the probabilities were quite against such contingencies, and the Supreme Commander was advised accordingly.

The decision to defer the assault from 5 June was made provisionally on 3 June and confirmed early on 4 June on a forecast of high winds and overcast skies in the Channel area. The actual conditions were as forecast; it was not until well into 5 June that the low cloud began to break to any operationally useful extent and wind continued fresh in the beachhead seas until the evening of that day. It is, therefore, fairly certain that the weather conditions on the Normandy coasts during the crucial hours immediately before, and at the scheduled time of, launching the assault were prohibitive, at least in regard to airborne troop landings and the actual landings on the beaches: the heavy bombers would certainly have had to operate by non-visual technique and the medium and fighter bombers would have been seriously hampered. Spotting by aircraft for naval bombardment would probably not have been practicable.

After the confirming of cancellation of the operation early on 4 June, no one knew when the operation could again be proceeded with : the weather situation looked as uncompromising as it could be. The Chief Meteorological Officer and, doubtless, others seriously considered the more distant alternatives which were,

after 6 June, the 8th and then about the 17th, a fortnight later. Towards evening of the 4th, however, quite unexpected developments were seen to be taking place in the synoptic situation which might just allow a brief, but perhaps long enough, improvement for the first and most critical landings to be effected. The matter was reported to the Supreme Commander and a meeting of the Force Commanders was called. After much cross-questioning on the details of the weather in this interval and on the likely conditions on the following days, the Supreme Commander issued provisional instructions for the assault to be launched at 0630 hours on Tuesday morning. After a further conference in the early hours of 5 June, these instructions became final and irrevocable.

The conditions actually realised in the hours immediately preceding and following the landings, though not ideal or even the complete minimum requirements, were decidedly better than on the preceding and succeeding days. The surface wind and, therefore, the sea roughness, had moderated during the evening of the 5th; and the amount of cloud and the height of its base at various times of the night and early morning were such as to allow all phases of the assault to be carried out according to plan. In particular, the conditions for airborne landings were somewhat better than forecast in that the cloud ceiling was at the unusual height of 4,000–5,000 feet, and by the time the heavy bombers were due to operate, the cloud was broken enough to allow use of visual technique. The medium and fighter bombers were not hampered, nor were the spotting aircraft. The wind conditions on the beaches were within the limits set, though the sea and surf still suffered from the stronger winds of 4 and 5 June. The Supreme Commander and his Staff could not have been surprised at the deterioration of the weather on 6 and 7 June, as this deterioration had been emphasised at the meetings leading to the final decision.[1]

The Supreme Commander's meteorological advisers had given much consideration on 4 June to the question of whether conditions for an assault on Tuesday, 6 June would be more or less favourable than on Thursday 8 June. They understood that as the assault forces from greater distances were already at sea, at least some of them would need to return to base for about 12 hours if decisions went against launching the assault on Tuesday. This would preclude an assault on Wednesday 7 June. In this connection, the alternatives from the meteorological point of view were :—

(*a*) A reasonable confidence in a favourable interval, even if of limited duration, just before and at the time of an assault on Tuesday 6 June.

(*b*) Less confidence in an only possibly better interval on Thursday morning, 8 June.

In view of the extent to which the whole weather situation had so quickly and intensely been disturbed since Thursday 1 June, and the proneness of disturbed conditions to continue once they had started, particularly when that start had been so violent for the time of the year, it was considered that alternative (*a*) should be emphasised in the advice given to the Supreme Commander. If, in fact, the weather developed so that Thursday 8 June would have been a better day of the assault, then those conditions would be equally valuable for the

[1] *See* Appendix No. 11 for a summary of the weather in Normandy and the Channel during the period 4–9 June.

immediate follow-up phase of the operation; whereas, if the opportunity of favourable conditions overnight 5–6 June were missed, and if information on Monday and Tuesday showed that Thursday would be less favourable than it seemed on Sunday (4th), then the whole position would have become extremely serious from the viewpoint of holding up such a large and complex operation.

In fact, the weather overnight 7–8 June was probably not as good as the weather from midnight on Monday 5 to early Tuesday 6 June. During Thursday, wind increased to Force 6 accompanied by multilayer clouds and rain; by evening winds were mainly Force 6. These conditions continued throughout the 9th with overcast skies of multi-layer cloud with its base at times down to 500 feet.

It the Supreme Commander had found it impracticable to decide on a date in the first batch of scheduled dates (5–8 June), other than meteorological reasons would have necessitated a postponement for 12 to 14 days. The early hours of 17 June might have been just favourable for the actual assault but the immediately following days would have been prohibitive for the follow-up and early build-up phases. Force 5 winds with Force 6 and even 7 at times from a northeasterly direction with long periods of overcast sky and low ceiling (1,000 feet or less) would have seriously hampered all naval and most air operations, as indeed they did, though at a somewhat less critical stage of the operation.[1]

* * * * *

The planning and the execution of the plans for the landings in France provided certain lessons in meteorological work and organisation. For instance, if meteorological conditions have to be taken into account in the planning of a complex operation, a meteorologist should be brought in at the earliest phases before the plans have so far crystallised that it would be difficult to alter them. The meteorologist should also be appointed to the staff of the Supreme Commander, *i.e.* he should be in uniform and be subject to the same code of rules, security, etc., as other members of the planning staff. Moreover, this would facilitate his taking action with the senior staffs of Allied armies who might not be acquainted with the staffing arrangements of Meteorological Services other than their own.

The magnitude, range and complexity of the military and political factors concerned in the NEPTUNE operation limited elasticity in decision. Even such details as tides, light and clearance of underwater obstacles practically pre-determined when such amphibious operations should be launched. Nevertheless, NEPTUNE was postponed because of a forecast of bad weather: and when it was postponed, no one knew when the operation was likely to be put on again. It might well have been further deferred if the weather had continued unfavourable. Thus, however complex an operation might be, the meteorologist should do his utmost to ensure that the plans include provision for possible postponement because of weather. From the meteorological point of view, it would be even better if the plans could also allow for the dates for the operation to be brought forward, but this might not always be practicable.

[1] *See* Appendix No. 11 for a summary of the weather in the assault area during the period 17–21 June.

In the months preceding the actual operation the Supreme Commander arranged for meteorological briefings for dummy D Days to be given. It was realised that the making of the final decision, taking into account the likely weather conditions, was an important phase of the whole operation and needed rehearsal like all other aspects of the operation. This effective and profitable innovation in military operations which will doubtless be followed in any similar operations in the future might have been even more profitable if the weather in South England and the Channel in the weeks before the landing had not been so consistently good. The complete break in the weather just at the time when the real decision had to be made introduced complications which could hardly have been foreseen against the background of blue skies and light winds of the preceding weeks.

The telephone conferences with the forecasting centres and the Meteorological Staff Officers of the Force Commanders had a dual purpose :—

(*a*) To provide the Chief Meteorological Officer SHAEF with the best information on which to base his oral advice to the Supreme Commander.

(*b*) To define the wording of a statement, not inconsistent with (*a*), in precise meteorological terms for issue to the meteorological officers at the main H.Q. of operational formations.

As the aim was to cover a period of five days from the day of issue, the effort to produce the degree of definition required for (*b*) often resulted in statements which were hardly justified by the existing inexact state of medium or long range forecasting and which, indeed, did not always make strict meteorological sense. As the advice needed for (*a*) could not be divorced from (*b*) this must sometimes have resulted in the Chief Meteorological Officer having to submit to the Supreme Commander a less clear picture of events than he would have wished. If, for example, on day n minus 3 the analysis of one forecasting centre A led to that centre forecasting the arrival of a front over the operational area in the early morning of day n, whereas B's analysis timed the arrival of the front for the evening of day n, and the third centre C thought the same front would appear some time between the times of A and B, the Chairman could hardly have claimed to be a meteorological adviser if he had rejected A and C as being wrong and accepted B's analysis. In such circumstances, the inevitable outcome was that in attempting to time specific weather events more than a day ahead, it was necessary to spread the weather likely to be associated with that event over a longer period than any single forecaster would have allowed. Indeed, it was primarily this aspect of the conference which caused the Meteorological Section SHAEF to abandon the attempt to prepare a series of synoptic charts to go with the forecasts submitted to the Supreme Commander. In the early days, prebaratic synoptic charts were, in fact, prepared before the conference, on day n minus 3, for each of the days n minus 2 to n plus 2, but it soon became clear that while the charts for day n minus 2 might survive the conference with only one or two alternative dispositions of pressure centres and fronts, the chart for day n minus 1 had at least two primary and some secondary variants from each forecasting centre.

Had they been readily available, aids such as 'Facsimile' reproduction processes for the quick interchange of synoptic charts by line or radio processes might have reduced some of the differences of opinion of autonomous forecasting centres by ensuring that each of them at least realised the different premises which the others were using. It is doubtful, however, whether, in some of the meteorological events which occurred during the conference, in particular that of the most critical occasion on 3 June when the interpretation of a single report from a ship was all important, an interchange of synoptic charts by 'Facsimile' or any similar process would produce a unanimous opinion. A forecasting centre naturally adopts that interpretation which is best fitted to its general trend of analysis at the time, and it was soon found that the difficulties of agreeing on a forecast were not lessened by some of the centres coming to the conference with their own logically consistent analysis and sequence of weather, all defined even to the extent of the phraseology to be used in drawing up the final statement. This procedure could not have led to easy modification in the light of discussion, for even if time had allowed recasting, the representatives of the centres which adopted this procedure would clearly have found it impracticable to align their ideas along new processes of weather development suddenly propounded by other centres. This difficulty was only partly overcome by arranging to hold, a few hours ahead of each main conference, a preliminary conference at which the centres discussed the lines on which they were thinking about the synoptic development of the next five days.

A solution to these difficulties needs to be found before any future emergency arises. Undoubtedly, the simplest solution would be for the various national authorities to agree to form one Supreme forecasting centre at which the best qualified and most experienced representatives of the various meteorological services concerned could work together: these experts could then discuss their differences with the charts and basic information before them instead of working unseen in separate institutions, and not all with the same basic information and same synoptic charts. For this procedure to be adopted, it would have to be agreed beforehand that the forecasts issued by the Supreme Centre would be accepted by all services involved in the operation. This type of arrangement certainly works on the military side, and it should be determined whether meteorological services could fit into a similar framework. Another, but less sound, solution might be to restrict the functions of the conference to providing an exchange of views about analysis and future trends and developments without requiring the chairman to produce during the conference a statement on the development and weather acceptable to all participants. Supplied with his own information and charts, he would use his own judgment about which, if any, of the views offered he would adopt for the advice to be presented and this advice would form the framework within which the co-ordinated forecasts for distribution of the operational formations would be cast.

It is doubtful whether the views of any of the forecasting centres were influenced during the critical period before D day by any of the semi-statistical approaches to long range forecasting which were used, but these may have been useful in confirming views arrived at by more normal synoptic methods and may, therefore, have affected the confidence with which their views were put forward at the conferences. Even with the combination of semi-statistical, semi-synoptic techniques used by the British and U.S. Services, it was found that the accuracy of the five-day forecasts fell away sharply after the first two days of the period to which they referred. An examination of the

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five-day statements, submitted to the Supreme Commander during the abnormally stable conditions of April and May 1944, shows that their operational value decreased substantially after the second day from the day of issue. It will be realised that when the synoptic situation changed rapidly, the forecasts often needed considerable modification before the first day was past. If specific details of cloud, wind and visibilities for limited areas had had to be included in each statement, even this 24-hour period might well have been too long in some types of British weather. The obvious lesson is that the various Meteorological Services should continue to try to improve their techniques for extending weather forecasts beyond 24 hours, and, as progress is made, so should military staff be advised of the degree of accuracy with which such forecasts can be made for given periods ahead. Although it is possible, for help in planning, to provide statements to the effect that 'weather is likely to continue unsettled with considerable general cloudiness though with intervals of well-broken cloud and good visibility' or in rarer circumstances, that 'mainly settled weather will probably persist for the next few days with light, moderate northwesterly wind and well broken cloud, minimum at night', a technique remains to be discovered by which first approximations to such details of weather as are needed for specialised operations can be forecast with useful accuracy, as a regular procedure, for more than two or even one day ahead.

* * * * *

H.Q. Allied Expeditionary Air Forces

Although all Air Forces under Supreme Command were controlled by the Air Commander-in-Chief and his combined British—U.S. Staff, the meteorological staff at his H.Q. had little more than liaison responsibilities for the meteorological services at formations and units, their function being to ensure co-ordination by mutual consent rather than to control, and to assist in smooth working by handling such matters as were formally best dealt with in parallel with normal Service channels. Such duties, although important, were of no historical significance except as demonstrating how Allied meteorological services could be smoothly co-ordinated without the need for actual integration.

The first meteorological appointment to the H.Q. A.E.A.F. was a U.S. Colonel late in 1943. By virtue of his prior appointment and his service seniority, he retained the formal position of Head of the Section when a British civilian was appointed as Chief Meteorological Officer (British) in March 1944. The latter remained a civilian until August 1944 when he went into uniform with the acting rank of Group Captain before proceeding to France. While efficiency probably did not suffer significantly from the appointment of a civilian as opposite number to a Colonel in the U.S. Service, Staff Officers of both nationalities undoubtedly were much more ready to discuss Service matters with the officer in uniform, and the civilian representing the British Service, did not find the position congenial or conducive to good liaison.

Apart from its miscellaneous duties, the Section did little, before the landing in France, but take part in the telephone meteorological discussions between SHAEF and the Central Forecasting Office (C.F.O.), and pass on general meteorological forecasts to the Staff at the regular morning conferences. It had no forecasting unit and was authorised by D.M.O. to make full use of the facilities of the section with H.Q. Fighter Command at Stanmore which was

located in the same building. The U.S. Chief Meteorological Officer did not regard himself as a scientific forecaster but as a Staff Officer taking the opinion agreed by the main C.F.O.s and presenting this in operational language.

Throughout the existence of H.Q. A.E.A.F., very few operational decisions appear to have been taken on the basis of the meteorological advice presented at the H.Q. The major landing decision was made at Supreme H.Q. level and thenceforward the Air Forces concerned operated with a large measure of independence, the final weather decision being made almost invariably at a lower level than H.Q. A.E.A.F. Nevertheless, meteorological advice was needed in allocating the tasks of the Air Forces at the A.O.C.-in-C.'s conferences, which were at a very high level as H.Q. A.E.A.F. was used as a meeting place for Senior Commanders of British and U.S. Navy, Army and Air Forces. Thus the technical forecast service provided was an essential item in the complexity of meteorological services, but needed for its efficiency the balanced overall assessment of the position by a Staff Officer aware of the co-ordinated opinions being expressed elsewhere more than an independent judgment of the meteorology of the situation.

In July 1944, the Chief U.S. Meteorological Officer proceeded to France with the designation of Chief Meteorological Officer A.E.A.F. (Overseas) with the primary, almost exclusive, duty of arranging for the re-establishment of the French Meteorological Services. The Chief Meteorological Officer (British) then assumed the responsibilities for continuing the service provided at H.Q. A.E.A.F. (Main) still at Stanmore with the technical aid of the Senior Meteorological Officer, Fighter Command. On 7 September the Chief Meteorological Officer (British) also moved to France in order to maintain liaison with the U.S. Weather Service which had moved its H.Q. somewhat earlier, and to ensure satisfactory meteorological arrangements for H.Q. A.E.A.F. on the Continent.

21st Army Group and 2nd T.A.F.

Before 1940, there was no experience of a meteorological organisation suited to the conditions of mobile warfare, but the experience of meteorological officers who returned from France in 1940 and that of the meteorological sections with the Army and R.A.F. in N. Africa provided a basis on which to begin designing an appropriate meteorological organisation for an invasion force. These preliminary ideas were tested on the pre-invasion exercise 'SPARTAN', held in southern England in March 1943, which was a large scale exercise in the opposition of two armies, each with co-operating Air Forces. The respective armies were the 2nd, with 'Z' composite R.A.F. Group, and the 6th, with 'X' composite R.A.F. Group. Meteorological sections were attached to each of X and Z Composite Groups, and also to the H.Q. of each Army, but early in the exercise, these were combined with the meteorological sections of the corresponding Composite Group H.Q. Below the level of Army H.Q., there were meteorological sections with Corps H.Q. but not with lower formations. When SPARTAN ended, X composite group was disbanded but Z Group remained in a modified form, training for its ultimate role by operating over France under the control of Fighter Command. It formed the nucleus of what was later known as No. 83 Group, and as it retained its meteorological section, valuable experience of operational requirements was obtained. Later in 1943, further experience was gained and plans tested by meteorological sections in a number of other exercises.

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Meteorological Organisation

Experience showed that the meteorological service for the expeditionary forces should either be completely self contained or so closely bound up with the military organisation as to form an integral part of it, and to be regarded as such by that organisation. Only thus could facilities such as transport, signals, etc. be provided. The shortage of manpower and supplies was a formidable difficulty in the way of the first alternative and, as to the second, the Meteorological Office had found no difficulty in integrating meteorological sections with relevant R.A.F. H.Q. Further, after SPARTAN, the principle was adopted of joint Army/R.A.F. H.Q. at the levels of Army Group and Army, and since meteorological sections at Army H.Q. level had found it advisable to combine with that at R.A.F. Group H.Q., it was natural to propose that the meteorological sections at those levels should form an integral part of the joint H.Q. Following from this, meteorological sections would have to depend on the R.A.F. or Army as appropriate to provide necessary facilities.

About a month after SPARTAN, Z Composite Group became No. 83 Group, R.A.F., temporarily under the control of Fighter Command. The first step, on the military side, to provide an appropriate meteorological service was taken by the A.O.C.-in-C., Fighter Command in April 1943, when he asked the Meteorological Office to provide meteorological sections at Group H.Q., at No. 1 Mobile Operations Unit and at each airfield, of which there were then four.[1] Following correspondence on this matter, Fighter Command raised the question, in July 1943, of the meteorological establishment of the Second Tactical Air Force, then forming, as a whole. Requirements, which were notified to the Meteorological Office in August 1943, included :—

Air H.Q., 2nd Tactical Air Force ..	Type 1 Met. Office.
Air H.Q., Nos. 83 and 84 Groups ..	Type 1 Met. Office.
Air H.Q., No. 34 P.R.U. Wing	Type 2 Met. Office.
Air H.Q., Airfields	Type 4 Met. Office.

Meanwhile, the Type 1 Meteorological Office with G.H.Q., Home Forces, had been taken over as the meteorological section of H.Q., Twenty-first Army Group. As a temporary measure, the Senior Meteorological Officer of this section acted as liaison officer at H.Q., 2nd T.A.F. until finally, in September 1943, the whole section transferred to that H.Q., becoming the Type 1 Meteorological Office of the joint H.Q., Twenty-first Army Group/2nd T.A.F.

Steps were taken in August 1943 to provide the meteorological sections needed by No. 84 Group, then forming. No action was needed for No. 34 P.R.U. Wing as it came over to 2nd T.A.F. with its existing meteorological section. No. 2 Group already had meteorological sections at H.Q. and airfields when it was transferred to 2nd T.A.F. in August 1943, so that no immediate action was necessary when that occurred.

Hitherto, the meteorological sections with Corps H.Q. had been regarded as the principal sections in the Army organisation, but the War Office acceptance of the arrangement of having one Type 1 office at joint Army/R.A.F. H.Q. made a reconsideration of the whole organisation possible. With the formation of Twenty-first Army Group, comprising the 2nd British and 1st Canadian Armies, in the summer of 1943, and the subsequent formation of

[1] F.C/S.29260/Nav.

2nd T.A.F., one Senior Meteorological Officer was appointed to serve the joint Twenty-first Army Group/2nd T.A.F. H.Q. Similarly, the Senior Meteorological Officers of Nos. 83 and 84 Groups worked in that capacity for the associated Armies.

This novel structure at higher Army formations made possible a complete reconsideration of the structure of lower formations. After discussions between the Air Ministry and War Office, it was proposed in April 1943, to reduce the size of the Corps meteorological section on the assumption of good signals facilities between the sections at Corps and Army level. It was also decided to revive the meteorological sections with lower formations, the final proposals being put to the War Office in June 1943.[1] In addition, a mobile upper wind observing section was proposed, on a scale of one for each Corps, to make observations for Meteor artillery reports in forward operational areas. It was later agreed that a meteorological section should be provided for Survey Regiments. Such a section could be split into two, and work one with each Company. These arrangements were made for the British Army. The First Canadian Army had its own meteorological units, staffed by Canadian Army personnel. The meteorological 'group' of the Canadian Army, however readily fell into line with the Air Ministry–War Office arrangements, being most anxious to ensure conformity. On the military side, the Canadian Army meteorological 'group' was under the G.S.O.1 of the Canadian Army Staff, but on technical matters they complied with the instructions issued by the Senior Meteorological Officer, H.Q. No. 84 Group.

After considering the needs of the Expeditionary Forces as a whole, the final proposals of the Director of the Meteorological Office as to the establishments for 2nd T.A.F. were communicated to the Air Marshal Commanding in December 1943.[2] The A.E.A.F. formations of No. 83 Group were included in the proposals as the requirements of the R.A.F. units of the Allied Expeditionary Air Forces were being considered as a whole. Later, on a revised policy decision, the meteorological sections at the Group Control Centres were abolished in May 1944 and their functions taken over by the sections at Group H.Q. In May, a meteorological establishment was also agreed for No. 85 Group. On the Army side of the organisation, the War Office accepted the proposals of the Meteorological Office.[3]

Accommodation and Transport

The only specialised mobile equipment held by meteorological sections before SPARTAN was a 30-cwt. wireless truck used by Corps meteorological sections for the interception of wireless weather messages. For any operation or exercise in the Field, it was necessary to improvise a mobile office in any suitable vehicle such as a 3-ton load carrier. Improvised arrangements such as these were made for SPARTAN, but as the result of experience, it was recommended that specialised vehicles, together with drivers, should be provided exclusively for the use of meteorological sections. It was recommended that for H.Q. Army Group/R.A.F. Command and Army/R.A.F. Group, two Mobile Offices, one 3-ton lorry and one heavy passenger car should be provided. For H.Q. Corps, one mobile office, one 3-ton lorry, one small

[1] A.M. Files S.37349 and S.94048.
[2] A.M. File S.92836.
[3] A.M. File S.94048.

utility van and one motor cycle should be provided. The two mobile offices at H.Q. Army/R.A.F. were necessary to permit 'leap-frogging.' It was also recommended that they should be specially fitted vehicles with suitable lighting, 'black-out' and electric power points. The 3-ton lorries were needed as load carriers, and the passenger transport to assist in leap-frog moves and the carrying of related small equipment.

The advantage of a specialised mobile office for meteorological purposes was proved by the Meteorological Section H.Q. No. 83 Group, who obtained on loan one of the mobile offices of the U.S.A.A.F.[1] meteorological service. The establishment of transport needed by 2nd T.A.F. was approved in February 1944, but when steps were taken to implement it in March 1944, it was found that office vehicles were very scarce and no meteorological section ever obtained the establishment approved. Apart from receiving one or two Fordson office vehicles at the level of H.Q. T.A.F. and R.A.F. Group, no specialised vehicles were provided; the mobile offices used by meteorological sections generally were modified load carriers and owed much to individual ingenuity and skill in adaptation.

Representatives of the Meteorological Office and the War Office discussed in July 1943 the transport requirements of Army meteorological sections. At first a 15-cwt. mobile office was chosen, but the Meteorological Section, H.Q. VIII Corps questioned its suitability, and a 3-ton vehicle was later recommended. The War Office were asked in November 1943 to provide mobile offices and transport on a specified scale. This was agreed, but again the supply position was such that meteorological sections with the Army never obtained the mobile offices and transport considered necessary by the Air Ministry and the War Office. As on the R.A.F. side, however, meteorological officers were ingenious and skilful in adapting their transport to their needs.[2]

It was the common experience that lack of specialised mobile offices handicapped meteorological sections in their work, and the absorption with such problems as how to ensure adequate lighting by day and complete black out by night in a 3-ton load carrier did not help concentration on the daily problem of forecasting the weather. An additional handicap to the Army meteorological sections was their liability to lose what transport they had.

Communications

Swift and reliable communications are a basic necessity for an efficient forecasting service. Meteorological sections require comprehensive signals communications permitting the interchange of weather reports with other meteorological sections and the receipt of synoptic weather reports from one or more meteorological centres. In the Field, it was necessary to plan first for dependence on wireless communications and then for line communications at some later stage when more or less static conditions had been reached. The Type 1 offices were regarded as meteorological centres and it was essential that they should have intercommunication. The lower meteorological sections had to have communications with a meteorological centre to receive forecasts and information from above and to transmit to the local centre local weather reports and request for forecasts.

[1] A.M. File S.96044.

[2] A.M. File S.83666.

The Signals Branch of the R.A.F. provided the signals facilities needed by sections working with R.A.F. formations and units. The first essential was to ensure reception of the Air Ministry ALFIG synoptic wireless issues of weather reports from Great Britain and the eastern North Atlantic. These issues were not specifically designed for the use of invasion forces, but from the time of SPARTAN, they were modified to adapt them more to the needs of these Forces. It was realised in March 1944, when the meteorological arrangements for the Allied Expeditionary Force were being discussed that a second channel ALFIG broadcast would be needed and, in fact, this second broadcast was started soon afterwards, its code name being BULFEX. ALFIG and BULFEX broadcasts provided most of the material used by the forecasting sections of the expeditionary forces in the construction of their weather maps, so long as wireless was used. The rest of the data used in the weather maps was provided in the 2nd T.A.F. broadcast which provided intercommunication between the Type 1 meteorological sections of the British Expeditionary Forces on W/T transmitters specifically allocated for meteorological broadcasts. This programme was later modified to meet changing conditions.[1] For communication downward from the Type 1 meteorological section at R.A.F. Group H.Q. to the Type 4 sections at airfields, the 'common-user' Group wireless broadcast was used quite successfully. Thus airfields could obtain forecasts, etc., from Group H.Q.

When plans were first mooted to meet the eventuality of a static phase in operations, provision of line communications for meteorological purposes was not sympathetically considered by the Signals Branch of H.Q. 2nd T.A.F., but after the landings, when the importance of meteorological reporting back from France to England was indicated by Bomber Command, higher priority was given to meteorological communications and a meteorological teleprinter network linking Dunstable, H.Q. 2nd T.A.F., H.Q. No. 2 Group, No. 83 Group, No. 84 Group, No. 34 Wing and No. 24 Sector (No. 85 Group) was ultimately provided. Group H.Q.s were linked by telephone to relevant airfields and when the static phase was reached, the line signals organisation approximated to that in use in the United Kingdom.

For meteorological sections with Corps H.Q. and below, the War Office were required to ensure signals such that Corps meteorological sections could intercept selected portions of ALFIG and of the relevant R.A.F. Group General Purpose Broadcast, and that all meteorological sections could transmit local weather reports back to the Type 1 office at H.Q. Army level and receive forecasts from that section. The War Office took the view, not shared by Twenty-first Army Group, that adequate facilities had been provided to meet these requirements. At the time of the landings in France, the position was that the signals facilities would be provided if the prevailing operational conditions permitted, but the relevant Commander in the Field was to decide the priority of meteorological requirements relative to others.

At first, during SPARTAN for example, pad cyphers were used, but by the time of the landings on the Continent, C.D.0277 and C.D.0278 had been introduced with a consequent increase in convenience. Pad cyphers continued in use for forward Army meteorological sections which were liable to capture by

[1] A.M. File S.92837.

the enemy. The quality of cyphering at Dunstable improved as time passed. Units in the field became to be accustomed to the cypher work that ultimately great skill was acquired and no hindrance to work, apart from the inevitable delay, was experienced.

France and N.W. Europe (June 1944–May 1945)

The Senior Meteorological Officer of Twenty-first Army Group/2nd T.A.F. received particulars of the OVERLORD plan in August 1943. From then onwards he was required by the planning staff at H.Q. Twenty-first Army Group to prepare for different periods during May and June a number of statistical reports covering the cross-channel route to Normandy and referring to the frequency of spells of quiet days during which the wind did not exceed Force 3. When H.Q. 2nd T.A.F. moved to Uxbridge in February 1944, the meteorological section moved with it. Daily at 9 a.m. the Senior Meteorological Officer took the synoptic charts to the A.O.C.-in-C. and his staff, to give the forecast for the day and the general weather outlook for air operations; this routine was maintained throughout the whole campaign. Meteorological conferences at Portsmouth were conducted by the Chief Meteorological Officer, SHAEF, and are mentioned to record that the Commander-in-Chief, Twenty-first Army Group, who was with the Supreme Allied Commander, was briefed as to the weather for the assault by the Chief Meteorological Officer, SHAEF.

Build-up of Meteorological Organisation

The meteorological sections which formed part of the formations or units specified below landed on the date indicated :—

7 June 1944	H.Q. 51st Division.
	H.Q. 3rd (Cdn) Division.
	H.Q. 50th Division.
	H.Q. No. 4 Survey Regiment.
8 June 1944	H.Q. I Corps.
	H.Q. No. 4 A.G.R.A.
	H.Q. 3rd (Br) Division.
	H.Q. No. 9 Survey Regiment.
9 June 1944	H.Q. 7th Armoured Division.
11 June 1944	H.Q. No. 5 A.G.R.A.
12 June 1944	H.Q. No. 93 Group R.A.F.
	H.Q. 49th Division.
13 June 1944	H.Q. XXX Corps.
	H.Q. No. 144 Wing R.A.F.
15 June 1944	H.Q. No. 127 Wing R.A.F.
	H.Q. No. 126 Wing R.A.F.
17 June 1944	H.Q. No. 121 Wing R.A.F.
	H.Q. 15th Division.
	H.Q. VIII Corps.
18 June 1944	H.Q. No. 8 A.G.R.A.
	H.Q. No. 124 Wing R.A.F.
20 June 1944	H.Q. 43rd Division.
24 June 1944	H.Q. No. 10 Survey Regiment.
	H.Q. No. 125 Wing R.A.F.

25 June 1944	H.Q. XII Corps.
	H.Q. No. 7 Survey Regiment.
	H.Q. No. 122 Wing R.A.F.
26 June 1944	H.Q. No. 129 Wing R.A.F.
	H.Q. No. 143 Wing R.A.F.
27 June 1944	H.Q. 53rd Division.
	H.Q. 59th Division.
	H.Q. No. 3 A.G.R.A.

Except for the sections with H.Q. No. 9 A.G.R.A., H.Q. 11th Armoured Division and the No. 83 Group Support Unit, all the meteorological sections of the Second Army and No. 83 Group R.A.F. were ashore in France by 30 June. There were no casualties due to enemy action but a small amount of technical equipment was lost in the sea at the first landings and a few minor items were destroyed by enemy action.

Until the landing of the section with the H.Q. I Corps, meteorological sections could only supply reports based on their own observations but a skeleton forecasting service was provided after the arrival of I Corps. This meteorological section of I Corps met the needs of all units ashore until D plus 6 when the first echelon of H.Q. No. 83 Group landed with its meteorological section. From D plus 6, the build up of meteorological sections proceeded as shown above so that by 30 June, the formations and units in the field could be served by the Army/R.A.F. Group meteorological organisation, as planned.

Local observations were reported back to the United Kingdom through H.Q. 2nd T.A.F., by the meteorological section of H.Q. I Corps on the Air Support Signals Unit network, but after two days this channel was closed as G (Air) Twenty-first Army Group found it was becoming too congested by non-priority traffic. With H.Q. No. 83 Group established in Normandy, the planned signals arrangements worked well in a downward direction, but observations reported to H.Q. 2nd T.A.F. for the T.A.F. meteorological broadcast, by the normal point-to-point wireless channel or by V.H.F. teleprinters were often subject to long delay. All possible methods of transmission were used in the first ten days, dictated partly by the relative locations of the meteorological section, the Signals traffic office and the Air Formation Signals teleprinters, but none was really satisfactory. On D plus 15 a remote control transmitter for the T.A.F. meteorological broadcast was installed in the forecasting office of H.Q. No. 83 Group and apart from occasional minor interruptions, information was transmitted back to H.Q. 2nd T.A.F. on that channel. The meteorological section, H.Q. No. 83 Group was moved from a site near the Operations Room to one near the Signals traffic office to ensure strict timing in the broadcast schedule of information transmitted on the general purpose Group broadcast to lower formations and units, including those with the Army. This method of disseminating information worked well. The upward transmission of weather reports by meteorological sections of Corps and Wing H.Q. to Group H.Q. was effected by teleprinter, wireless or telephone, the last usually being the quickest and most reliable method.

Reception at Main H.Q. No. 83 Group of the ALFIG broadcasts from ETA began at 0400 G.M.T. on D plus 7 and continued, though subject at times to rather strong local interference, particularly at night. The experience of H.Q.

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Corps meteorological sections, which were all given facilities for intercepting selected parts of ALFIG, was similar. ALFIG was thrice jammed by the enemy for periods of about six hours on frequencies 8,600, 4,302 and 2,970 kc/s. The basic data broadcast in ALFIG was found to be mainly satisfactory apart from the fact that MANX issues were not made at intermediate hours as well as at synoptic hours. Reception of the BULFEX broadcasts from ETA was less satisfactory, apparently because the frequency on which it was broadcast was not suitable. Reception of H.Q. 2nd T.A.F. and No. 2 Group wireless issues on the T.A.F. meteorological broadcasts was fairly satisfactory although a number of corrupt messages, believed due to interference, were received.[1]

The meteorological service in the United Kingdom and as a whole was handicapped by not receiving local weather reports from Normandy regularly from the time of the first landings. Consequently, the advice given to R.A.F. units was less confident than before the landings, when certain information was available through Intelligence channels. Special priority on some channel of communication should have been arranged to ensure at least a five minute meteorological transmission once every three hours so that weather reports from the beachhead were available in the United Kingdom.

No. 85 (Base Defence) Group came under the command of the A.O.C.-in-C. 2nd T.A.F. on 12 August 1944, within the command of the Supreme Air Commander Allied Expeditionary Forces, but before then, formations and units of the Group began to move overseas. The Group was organised on the lines of a Fighter Group in the United Kingdom and, being needed for the defence of the beachhead, its formations and units began to move to the Continent next after those of No. 83 Group. From a meteorological point of view, the arrival of the Sectors and Wings was more important than the H.Q. whose meteorological section was administrative only. The meteorological section with 21 Sector arrived at Tocqueville on 7 July 1944 and began work for operations next day. Hourly observations were broadcast from 12 July when No. 21 Sector took over from No. 24 Sector, then still, in England, the time of the 2nd T.A.F. meteorological broadcast allotted to sectors of No. 85 Group. Interception of the ALFIG broadcasts began on the 8th and of the BULFEX and 2nd T.A.F. broadcasts on the 10th. The meteorological section of No. 142 Wing arrived in France on 25 July, but as forecasts for the Wing received by Traffic Control teleprinter from No. 21 Sector proved adequate, it did not start functioning then.

The Type 1 meteorological section of H.Q. 2nd T.A.F. ceased functioning at midnight (clock time) at Uxbridge on 3 August 1944, and began at the same time at Le Trenquay, lat. 49° 13′ 37·8″ N., long. 00° 49′ 26·2″ W. The continuity of work was maintained because the organisation of the H.Q. generally was designed to this end; in fact the meteorological section moved overseas in four parts.

Meteorological units of No. 84 Group began to move with the corresponding units of the Canadian Army and the Group H.Q. with its meteorological section moved over just after H.Q. 2nd T.A.F.

The British Chief Meteorological Officer moved to France on 7 September to maintain liaison with the U.S. Weather Service which had moved its H.Q. somewhat earlier, and to ensure that the meteorological arrangements for H.Q.

[1] B.A.F.O. File 268 (M.O. 5).

A.E.A.F. on the Continent were satisfactory. It was found that the U.S. Service had arranged to supply such advice as was needed to the H.Q., first in Normandy and later in Paris (Versailles) and there was no call to provide anything more than this. In this phase until December 1944, when the British Group Captain assumed the appointment of Chief Meteorological Officer, 2nd T.A.F., and a Wing Commander was appointed to the H.Q. at Versailles (now Air Staff SHAEF, H.Q. A.E.A.F. having been disbanded) the work continued to be mainly that of general liaison between the American and British Services and of dealing at SHAEF level concerning meteorological communications and the re-establishment of meteorological services in liberated countries.

One of the components of the meteorological group of vehicles at H.Q. 2nd T.A.F. was a wireless van, provided by the Signals Branch, with four receivers and one remote control transmitting key. As only three wireless operators were available on a shift, not all four receivers could be worked simultaneously. The large amount of wireless traffic in the beachhead involved much interference and stations also tended to drift off their frequency, but interception improved with experience. Broadcasts by ETA of ALFIG and BULFEX were the mainstay of the forecasting service in France in the first weeks of the landings. The quality of the broadcasts was generally good but there were occasional corruptions believed due to interference. A teleprinter circuit between ETA and H.Q. 2nd T.A.F. was established on 9 August 1944, but it was of little value at first. Two teleprinters and a switchboard were installed on 10 August, the circuits being of simplex type. By 20 August, subject to local and other faults, it was possible to: receive the ETA teleprinter broadcast at each of H.Q. 2nd T.A.F., No. 83 Group and No. 84 Group; transmit from H.Q. 2nd T.A.F. to ETA while receiving the ETA broadcast (working duplex); 'broadcast' the observations from Nos. 83 and 84 Groups to all other teleprinters connected to H.Q. 2nd T.A.F. during the silent period in the ETA broadcast (Nos. 83 and 84 Groups were each given half this silence period, apart from the time necessary to make the appropriate changes on the switchboard). Teleprinter connection between H.Q. 2nd T.A.F. and the formations of No. 85 Group was not made until September 1944, after the move to Brussels; as H.Q. 85 Group was not an operational H.Q., the teleprinter connection was made to the most important Sector H.Q.

Mobile Phase in Late Summer and Autumn 1944

The plans and steps to secure mobile offices for the meteorological sections were never implemented, as mentioned above, owing to shortage of mobile offices and the relatively low priority given to meteorological sections.[1] Instead of two Austin office tenders on their establishment, the Type 1 meteorological sections of H.Q. Army Group/2nd T.A.F. and Army/R.A.F. Group were issued with one Fordson office tender and one 3-ton truck. The meteorological section of H.Q. 2nd Army/No. 83 Group had in addition the loan of an American mobile meteorological office. The best use was made of these vehicles, which were adapted by rough carpentry and improvisation as meteorological offices, the greatest ingenuity being shown in the meteorological sections of No. 85 Group which were never issued with anything better than 3-ton trucks. The

[1] A.M. File S.96044.

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supply of the mobile offices which they were established to receive would have enabled the meteorological sections to work without the worry of building up their own offices each time they moved. An adapted 3-ton truck was bearable in the summer but an unpleasant office in the winter. The Meteorological Office had also agreed with the War Office on an establishment of W.D. vehicles for issue to, and use by, the meteorological sections working with the Army.[1] These sections, however, were less well served than the meteorological sections working with the R.A.F. even when they got vehicles, which were not of the type specified in the establishment.

In the mobile phase of operations, all sections had to rely on wireless as the main means of receiving the synoptic weather reports needed for the construction of weather maps. An attempt was made to use teleprinter communications between the main forecasting centres from 10 August, but with the move of H.Q. 2nd T.A.F. first to Amiens on 4 September and then to Brussels on 13 September, the use of land-line facilities was not a success and could not be relied on until after the latter date. To ensure the receipt of the BULFEX broadcast and to meet complaints as to its audibility, the Meteorological Office arranged for the night broadcasts to be made on a high-powered B.B.C. transmitter. The 2nd T.A.F. broadcast was designed as a method of informing all meteorological sections in the field of the weather reports made by all other similar meteorological sections. The U.S. Army meteorological sections had a similar type of broadcast on a more elaborate scale. British attempts to intercept the American wireless weather messages from the mobile units or from the collective transmitter WLGT in Paris were disappointing and the only satisfactory means of interchange of meteorological information between the British and American Forces was through ETA.[2]

In the United Kingdom, taking Bomber Command as representative, the meteorological offices at H.Q., Command and Groups were able to co-ordinate advice given for operations because of adequate land-line communications. No such arrangement was possible for the expeditionary forces under mobile conditions. In any case, operational control was exercised at the Group level. For that reason, Group meteorological sections worked largely independently and accordingly it was necessary to have strong sections at these levels as well as at H.Q. 2nd T.A.F. In general, the organisation in each of the Army/R.A.F. Groups worked independently of the other. Daily at 0900 hours, the Senior Meteorological Officer gave the Air Marshal Commanding 2nd T.A.F. and his staff a general weather outlook for the operational area for the next 24 hours. Immediately afterwards, a similar procedure was followed with the Chief of Staff of Twenty-first Army Group, who was, in addition, often interested in the general weather outlook for two or three days ahead. All other advice to the Staffs was normally given by the senior or duty forecaster. A similar procedure was followed at Group H.Q., but in addition to advising the Staffs, Group H.Q. had to distribute advisory forecasts, analysis messages, etc., to dependent meteorological sections within the relevant Group. The Group general purpose broadcast channel, which was very largely usurped by meteorological traffic, was used in the broadcasting of this advice. This might not have been permitted, had the progress of the battle involved more movement of H.Q. than actually occurred.

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[1] A.M. File S.83666. [2] B.A.F.O. File 294.

It might have been a better policy to abandon all idea of having in Western Europe a mobile 'clearing house' of meteorological information, as represented by the meteorological sections of 2nd T.A.F. and of the American equivalent H.Q., in favour of a high-powered meteorological centre in S. England with comprehensive signals facilities, specially for the benefit of the expeditionary forces. Under conditions of mobile warfare, and within wireless range of a station in England free from those conditions, the best arrangements would have been for all Type 1 meteorological sections to pass back their messages direct, if possible, to the static centre in England. The usual limitations in manpower, equipment, wireless frequencies, etc., would have been met but, if the requirement had been envisaged far enough ahead, it might have been possible to allocate the appropriate resources exclusively for a meteorological service with the expeditionary force. In fact, the need for this was later recognised by the establishment of the meteorological section at the Base Signals Centre.

With the H.Q. of the U.S. Weather Services located in France, and with the re-establishment of the French National Meteorological Service assigned as a responsibility of the U.S. Chief Meteorological Officer, it was natural for arrangements for communications in France to be largely in U.S. hands, except as directly concerned the service for 2nd T.A.F. The Chief Meteorological Officer (British) A.E.A.F. was doubtless in a position, however, to appreciate the difficulties and to receive some of the criticism as the position was far from satisfactory in regard to the collecting in France and re-transmission to England of weather information from France. The overwhelming importance of communications is exemplified by the fact that no criticism, of any moment, of the meteorological services was ventilated at H.Q. A.E.A.F., other than the lack of information from areas known to be occupied by the Allies.

Static Phase

This phase began with the advance into Belgium in September and, so far as meteorological sections were concerned, with the arrival in Brussels on 13 September of the section with H.Q. 2nd T.A.F. and Twenty-first Army Group. Throughout this, and the final phase, no major modification was made in the general meteorological organisation provided for the R.A.F. and Army. The system was by then well tried and had proved broadly satisfactory. The long static period during the winter with large forces established on the Continent requiring supplies and involving many communication flights, particularly between England, France and the Low Countries did, however, give time for thought not only by the meteorological staff but also by the operational authorities. Instead of a small stream-lined, mobile service for an invasion force, it was necessary to think more in terms of a territorial meteorological organisation to meet all requirements. The Chief Meteorological Officer reported that it was agreed with A.O.C.-in-C. and S.A.S.O. that it was essential to strengthen the H.Q. meteorological section both technically and administratively if it was to function efficiently as it had never been possible for the Chief Meteorological Officer to do much more than keep the machinery moving by making *ad hoc* decisions on urgent matters. After emphasising the wide scope of the meteorological service within 2nd T.A.F., the Chief Meteorological Officer stated that questions of co-ordination and re-establishment of services in Belgium, Holland and Denmark would have to be considered and that it

was urgently necessary to plan for a big change in general organisation and requirements for the Forces of Occupation. Although, during the campaign itself, there was little tangible result, the way was prepared for the post-war organisation which was planned and agreed with Air Ministry during this period.

The priority assigned to meteorological sections in the allotment of signals facilities had progressively improved with the growing realisation by the Air Staff at H.Q. 2nd T.A.F. that the meteorological organisation on the Continent was of vital importance to Bomber Command and to other Commands and Services in the United Kingdom and elsewhere. Accordingly a comparatively elaborate meteorological teleprinter system was provided linking ETA (two channels), H.Q. 2nd T.A.F., each of the H.Q.s Nos. 2, 83 and 84 Groups, H.Q. No. 24 Sector, H.Q. No. 34 P.R. Wing and Meteorological Office, Evere (Brussels Airport). The meteorological section of H.Q. 2nd T.A.F. functioned in a manner broadly like that of a Type 1 at a Group H.Q., on the teleprinter network in the United Kingdom, acting as clearing house and relay of all meteorological data from and to the British Expeditionary Forces.

It was proposed in the autumn of 1944 to transfer the 'nerve centre' of the teleprinter network from H.Q. 2nd T.A.F. to the Base Signals Centre to be set up at Ghent, in No. 85 Group, and by the end of the year arrangements were well advanced. The meteorological section of the Base Signals Centre began operating in February 1945 and relieved the meteorological section of H.Q. 2nd T.A.F. of the labour of clearing all the meteorological data between ETA and the British Expeditionary Forces. The quality of continental lines used for teleprinter circuits was not so high as that of lines in the United Kingdom, but the establishment of the section was a great advance. It was fitted with U.S. equipment (typing—reperforators) with the messages typed in clear alongside the punched characters on the tapes. The Base Signals Centre received information from stations and Groups of 2nd T.A.F. broadly on the United Kingdom system, from ETA over two circuits and also from the American meteorological centre on the Continent. All this information was reperforated on tapes. W/T listening watches were maintained on ALFIG, BULFEX and other broadcasts, and this information was perforated as necessary. From the total material it was then possible, with great elasticity, to make up broadcasts containing the best selection for the use of 2nd T.A.F. units.

It was not feasible to install teleprinter communications for meteorological sections with Army formations and units, and these still relied on the ALFIG and BULFEX wireless weather messages issued by ETA. It was during this period that the issue of BULFEX broadcasts on a B.B.C. transmitter, at night, was so valuable. These broadcasts were continually being reviewed and their contents modified to meet requirements. As they were used by all sections when teleprinters broke down, they were of fundamental importance. For forecasts, analyses, artillery Meteor reports, etc., sections with Army formations and units continued to depend on the R.A.F. Group general purpose broadcast which was given over increasingly to meteorological purposes as the static phase developed with consequent availability of other channels for other traffic. It became easier, during this phase, for lower formations and units to report their local observations to the H.Q. section at Army/R.A.F. Group level because of the greater ease with which telephone communications could

be used. Generally, however, dependence on Army communication channels was never very satisfactory.[1]

Meteorological co-ordination with the American Forces was effected through ETA and was reasonably satisfactory. Attempts to obtain weather reports from the American sector by intercepting their collective wireless issues had been a failure qualified only by some slight local successes by individual units.

Even in the static phase it was found that meteorological sections with Army formations and units were too close together to provide a reasonable network of observations in forward areas. At one time in the early mobile phase, there were nine meteorological sections on a six-kilometre stretch of road. In the static phase, greater dispersal of sections might have been expected but, in fact, from the meteorological point of view, an adequate network of observations in the forward area was provided by the reports from Corps H.Q., the other units being too close to these formations for their reports to be of great value. Much more important, was the build up of an adequate network of meteorological observations in the rear areas. This had to be improvised with the available personnel and facilities, but was never very satisfactory until the revival of the national meteorological services in the countries concerned.

The static period permitted the consideration of more adequate provision for upper air observations. In the middle of January 1945, No. 1401 (Meteorological) Flight arrived on the Continent and was based at Melsbroeck. It continued to operate, making vertical climbs and cross-country reconnaissances even to the forward areas, throughout the remainder of the campaign. It was invaluable for general forecasting and for computing ballistic temperatures.

From the early planning stage climatological enquiries had been dealt with, but the meteorological service made no provision for special staff to deal with such enquiries in the field. During the static period, questions concerning especially frost, thaw, snow, flood and ground conditions again arose, and the Army Chief of Staff was persuaded that a meteorologist working with his planning staff would be of great value. This work is not just a matter of supplying answers to formulated enquiries but of studying the problems which give rise to the enquiries and anticipating requirements. In January 1945, therefore, a Squadron Leader with geological as well as meteorological training was posted to H.Q. 2nd T.A.F. and worked intimately with Army Staff. He had made a special study of 'trafficability,' *i.e.*, the state of the ground as affecting the movement of different classes of vehicle, wheeled and tracked, and much interest was taken in his advice co-ordinated with that of the forecasting section. During the last phases, 'trafficability appreciations' were prepared and broadcast daily. This officer also dealt with forecasts of river conditions in liaison with Flood Control, likelihood of thaw, rate of drying of soil in normal spring conditions, chances of frozen ground in February and March, depth of frost penetration, climatological factors as affecting stores of perishable foodstuff. There were other miscellaneous enquiries every day. The conclusion would seem to be that planning authorities can well use advice on the meteorological aspects of a diversity of activities, in addition to the forecasting service, and that a qualified officer should be included in any comprehensive service.

[1] A.M. File S.69285/II.

Final Phase

The static phase, during which the meteorological services worked smoothly generally, ended with the crossing of the Rhine on 24 March 1945 and the subsequent rapid overrunning of Germany with the capitulation in the north on 5 May to the C.-in-C., Twenty-first Army Group and the total capitulation on 9 May. The meteorological section of H.Q. 2nd T.A.F. remained throughout with the Main H.Q. first in Brussels and then, after the move to Germany on 6 April, at Suchteln near Munchen Gladbach ; Main H.Q. Twenty-first Army Group moved alongside and the H.Q. of the meteorological service continued unbroken. Apart from the vital operational decision made at this H.Q. for the Rhine crossing, operational meteorological advice was almost entirely for the purpose of general co-ordination and intelligence. Each morning the A.O.C.-in-C. was briefed at his Staff conferences. Each evening a combined conference with Army Staff was attended by the Chief Meteorological Officer or his deputy and the Army Chief of Staff was personally briefed each morning. Doubtless the advice then given had some bearing on the operational decisions but the nature of operational control precluded the sort of meteorological planning which was standard practice at Group levels. Groups continued to discuss forecasts with Command by land-line as far as communications allowed and general forecasts were broadcast from Command H.Q., but as much interest was probably taken at Command H.Q. in the forecasts for transport and communication flying as for active operations.

Nos. 83 and 84 Groups maintained their short support tactical roles and their meteorological sections operated as independent sections advising for current operational decisions. Meteorological liaison and co-ordination was technical rather than operational. Both Group meteorological sections moved with their operational H.Q. by splitting into two parts for each move and so avoiding any break in the continuity of the forecasting service.

The Group meteorological sections served the relative Armies and continued to control all meteorological sections with Army formations. During the period there was a considerable number of changes in units under the Command of each Army, and for a time before mid-March, most British Army units were under Canadian Army Command. This meant that the meteorological section of H.Q. 84 Group was mainly concerned with the meteorological service for the Army but it was found that by simply acting in parallel with the general changes the meteorological services worked satisfactorily. The system of communications and the use of Radar wind-finding tended to strengthen Corps meteorological sections at the expense of lower formations in some cases.

No. 85 Group, operationally concerned with night fighters, became less active during the period. It remained almost static with its units mainly in Belgium and the meteorological sections were kept busy with the requirements of communication flights. The setting up of the Meteorological Signal Section at Base Signals Centre indicated the way in which unforeseen developments affected the meteorological services ; as this centre was an 85 Group unit, control of the Meteorological Signal Section inevitably became the responsibility of the Senior Meteorological Officer, No. 85 Group. Again, the setting up of a large static smoke screen for Antwerp led to the provision there of a small forecast unit which also came under the control of the Senior Meteorological Officer, No. 85 Group.

Units of No. 2 Group were not generally established on the Continent before February 1945, having previously worked from United Kingdom bases. From the technical aspect, the meteorological requirements of this Group, with day and night, light and medium bombers, were more exacting than those of other Groups of 2nd T.A.F. Meteorological planning was on much the same principle as with Bomber Command in England and, with day and night sorties in almost equal numbers, it was a case of non-stop activity in the meteorological section of Group H.Q. Although the Group was not mobile in the same sense as Nos. 83 and 84 Groups, nearly all Wings moved forward during April and, for a short time, a forward tactical H.Q. was maintained. Offensive operations of the Group decreased well before the final victory but were later replaced by transport duties on a considerable scale necessitating special meteorological advice.

Personnel strength was maintained, during the period, generally up to overall establishment and requirements, although deployment called for a large degree of elasticity, and new requirements were met by transferring personnel from sections disbanded or inactive or by reinforcements from the United Kingdom. This led to some administrative confusion as some paper establishments became vacant while other requirements were met by temporary postings. Ultimately an establishment ceiling was approved and the Command (in effect the Chief Meteorological Officer) had the authority to cancel, create or modify local establishments within the ceiling. This led to much smoother working with Organisation and Personnel Branches and may be commended as the only satisfactory workable system for a mobile force subject to frequent and rapid change in commitments.

With regard to communications, meteorological units with operating teleprinter connections remained well served. The mobile Groups, Nos. 83 and 84, remained linked by R/T through H.Q. 2nd T.A.F. but the forward circuits could not be maintained through the last highly mobile phases, so that the need for W/T working remained. In this respect, the inadequacy of the internal 2nd T.A.F. W/T arrangements for meteorological reports continued to be the weakest link in the whole system. For efficiency, the W/T provision for a mobile force should be carefully planned and every effort be made to secure two channels at least, one for collecting data from the units on point to point working and another at reasonably high power for broadcasting collectives. Within the static (or transportable) formations, Nos. 2 and 85 Groups, there was, with teleprinters and telephones, little difficulty, and within the mobile Groups separately, land-lines could be freely used for collection, while Group broadcasts also worked well. Local initiative also provided much better facilities than were authorised in the general communication plans and in several cases small signals units were provided by Groups to ensure communications with Corps meteorological sections. No. 83 Group ended the campaign by capturing intact the German meteorological radio and teleprinter centre at Quickborn–Pinneberg, near Hamburg, and retaining many land-line circuits in the Schleswig–Holstein and neighbouring areas for meteorological use, an achievement of the greatest value which did much towards securing the future efficiency of meteorological services.

By arrangement with the Director of the Meteorological Observatory, Uccle, a British radio-sonde station was established there in March and by the end of April was making four ascents daily. The need for accurate ballistic temperatures

created a demand for radio-sondes in the forward area which could not be met from available resources as it had not been previously planned, nor would it have been likely to appeal to the authorities in the early days of the invasion planning. If, in future, operations should require accurate temperature and humidity information for artillery or other requirements, it would probably be good policy to enlist the support of the Army or of other air formations which might be concerned, as was Bomber Command, even if the invasion Air Force itself, concerned only with high mobility and short period tactical operations, were little interested. The two G.L.III Radar equipments for upper wind measurements provided for the invasion force remained in use throughout. With continuous maintenance, they were reasonably reliable but the type was sensitive to movement and maintenance was not always adequate. The Army authorities became very aware of the value of the observations and in many cases Army equipments, of which there were many in the field with A.A. units, were earmarked for wind finding. As many as six G.L.III sections were at times operating simultaneously in the area.[1]

Services for Transport Command

Early in the Normandy campaign, No. 91 Forward Staging Post of Transport Command was established in France, as a kind of satellite of No. 83 Group, to act as an 'airport' for that Group. This was the first indication to the Meteorological Office that Transport Command were to establish Staging Posts within the Expeditionary Force which would require meteorological services. The Senior Meteorological Officer of No. 83 Group at once made improvised arrangements including the provision of airman meteorologists and equipment at No. 91 Staging Post, and the supply of information to that Post, as though it were one of the operational airfields of No. 83 Group. A wireless set was obtained for intercepting wireless weather messages and telephone facilities enabled the N.C.O.-in-charge of the meteorological unit to obtain forecasts from the meteorological section of H.Q. Army/R.A.F. Group. Meanwhile, appropriate steps were taken to ensure an establishment for the Meteorological Office to meet the new commitments, which developed very rapidly with the setting up of further Staging Posts, one for each Group and one for H.Q. 2nd T.A.F.; the required establishments were ultimately sanctioned.

With the establishment at H.Q. Twenty-first Army Group/2nd T.A.F. in Brussels, the airport at Brussels/Evere was the natural location for the Staging Post of the H.Q. and would obviously become most important for the whole Expeditionary Force. Action was accordingly taken at once to provide an appropriate meteorological unit manned by British personnel and dependent for advice and guidance on the meteorological section of H.Q. Army Group/2nd T.A.F. When Belgian meteorological personnel in the R.A.F. became available, they replaced the British, and a modified Type 2 meteorological office was built up. As the importance of the other Staging Posts increased, they too were provided with modified Type 2 offices. As usual, signals facilities were difficult to obtain, first because it was not clear whether 2nd T.A.F. or Transport Command was responsible for providing them. Then, when Transport Command tried to obtain the generous provision of wireless equipment which they had planned for the meteorological sections of Staging Posts, they found that the equipment was not available.

[1] A.M. File S.103982.

The Staging Post at Le Bourget, set up when H.Q. 2nd T.A.F. reached Brussels, was in a peculiar position, operating in the American sector and manned by ill-trained French personnel. Administratively, all R.A.F. units on the continent were controlled by 2nd T.A.F. and the Chief Meteorological Officer of 2nd T.A.F. was, therefore, responsible to the Commander-in-Chief for the meteorological service provided at Le Bourget. Manpower shortage prevented the provision of a British meteorological office, and, politically, it would have been undesirable as the French were being encouraged to go as far as they could in providing such a service. At first, therefore, in agreement with the Director of the French Meteorological Service, a small British meteorological detachment under a Flight Lieutenant was sent from Brussels to Le Bourget to train the French meteorologists there in meeting our requirements, and meanwhile to meet those requirements. After a short time, it was possible to withdraw the other ranks, leaving only the Flight Lieutenant as a liaison officer.

Services for the Army

Apart from the decision to launch the landings in France on 6 June, no decision for or against the launching of an Army operation was, so far as is known, made on the advice of the meteorologists alone. The Army used the meteorological service mainly in the conduct of operations. Meteorological sections supplied general weather forecasts for operations but their greatest value was in supplying specialised forecasts and observations for the operations of the Artillery (Artillery Meteor reports) sound ranging, smoke screens and trafficability. The last of these relied on climatological and geological considerations, and meteorological sections acted as little more than agencies in the dissemination of relevant information.

At first, artillery Meteor reports were supplied to artillery formations and units for a forecast period of six hours, but the period of the forecast was reduced to about two hours, with the aim of increasing efficiency, after the Major-General Royal Artillery, Twenty-first Army Group, had asked for special efforts to be made to improve the accuracy of the reports and, with that object, had arranged for the use of Army G.L.III radar sets in making upper wind observations. This particular recognition of the value of Meteor reports was made just before the reduction and capture of the island of Walcheren, and the technique then used was adopted for later operations of similar type.

The Army early appreciated the need of expert meteorological advice for the operation of smoke-screens. Such operations on the continent began on D Day when an anti-aircraft smoke screen was operated at Port en Bassin and Arromanches. The meteorological advice needed was given on the basis of forecasts obtained from a neighbouring forecasting unit and as interpreted by the N.C.O. meteorologist attached to pioneer company operating the screen. Small smoke screens were also operated at Caen and Cherbourg before the break out from Normandy, but the next major smoke screen operation was the provision of an anti-aircraft screen over Ostend. The meteorological advice for this screen was provided by the meteorological officer attached to No. 803 Pioneer Company, who obtained the necessary forecasts from the Type 1 meteorological section of H.Q. No. 84 Group. Meanwhile, experience in Normandy had suggested that smoke screens might be used tactically, for example, in screening operations to dislodge obstinate defence strong points,

and it was arranged to attach meteorological personnel to smoke companies used in this tactical role. For instance, meteorologists assisted in the screening operations of the Nijmegen bridge and of the Scheldt estuary. The screening of the Port of Antwerp was an important operation for which meteorological advice was at first supplied by the meteorological section of H.Q. No. 84 Group, through the meteorological officers attached to the various Smoke Pioneer Companies employed, but it was ultimately found necessary to set up a forecasting unit at Antwerp to deal with the work, at least until Smoke Companies began to break away for tactical operations elsewhere. The Smoke Companies came together again for the Rhine crossing and meteorological resources were pooled for the purpose of making appropriate forecasts. After the Rhine crossing, the Companies again split up and operated mainly on smaller tasks such as the capture of Arnhem and the clearing of N. Holland.

For meteorologists to understand the peculiar problems and requirements of the Army, they need to train with the Army formations or units to which they are attached, and the original idea of a pool of meteorological officers being established at H.Q. Army/Group and joining A.A. Brigades as necessary was not a good one.

The replacement of meteorologists of N.C.O. rank by N.C.Os. of the Pioneer Companies trained in meteorology was a good idea and worked well. These men proved to be efficient and the fact that they were in the Army and not in the R.A.F. simplified administration. It might be argued that in every case where meteorological personnel worked with the Army, their work would have been easier had they been in Army uniform, and administered by the Army, as those with the R.A.F. wore R.A.F. uniform and were administered by the R.A.F. It seemed that the Army in the Field could not get rid of the idea that because meteorological personnel were in R.A.F. uniform, their sole purpose was to serve the R.A.F.

Forecasting arrangements for smoke screens for OVERLORD were good. The meteorological officer with a Smoke Company was independent in that, on obtaining the necessary forecasts from the nearest appropriate meteorological section, he could give his expert advice as to dispositions without reference to higher authority.

The lack of adequate transport facilities was a continual handicap to the meteorologists; for their work with Smoke Pioneer Companies the 15 cwt. truck was considered most suitable.

Re-establishment of Meteorological Services in Liberated Countries

The early plans for OVERLORD envisaged the necessity for re-establishing national meteorological services in liberated countries. The responsibility for this was officially delegated in May 1944 by the Supreme Commander to the Air C.-in-C., A.E.A.F., and was automatically deputed to the Head of the Meteorological Section A.E.A.F., *i.e.* the U.S. Chief Meteorological Officer. Consultations with the Director of the Meteorological Office and the Director of the U.S. Weather Services resulted in agreement on the terms of a paper to be issued by the Air C.-in-C. as an 'Operational Policy Memorandum on Re-establishment of French Meteorological Service'.[1] To assist the Chief

[1] A.E.A.F./S.22364/Met.

Meteorological Officer in this work, two officers, a French-speaking American and a Belgian Wing Commander, R.A.F.V.R., were posted to the meteorological section of H.Q., A.E.A.F. Other Belgians of the R.A.F.V.R. Meteorological Branch, who had been recruited earlier by agreement with the Inspectorate of the Belgian Air Force with a view to ultimate employment in Belgium, were also made available. The responsibility in respect of Belgium, Holland and Denmark was assigned to 2nd T.A.F. during the winter 1944–1945.

From July 1944 until the end of the year, the A.E.A.F. Meteorological Section was actively occupied in re-establishing French meteorological observing stations, providing meteorological technical equipment from British sources, arranging communications, training French personnel in observing duties and providing them with the necessary facilities. With the liberation of Paris in August, the Office Nationale Meteorologique and its provisional director were contacted. Thereafter, action was co-ordinated with the French meteorological authorities and progress was rapid. Undoubtedly, the assistance given by the U.S. and British authorities working through the Supreme Commander, helped to put the French meteorological service on an effective working basis, to the benefit of all the Allies, much more rapidly than it would otherwise have been. Although important, the material aid was probably less valuable than the support of senior Staff officers at a time when everything was subject to military control and priorities. Although, by the end of 1944, the functions of the Meteorological Section, A.E.A.F. (later Air Staff SHAEF) were confined to occasional co-ordination and liaison work, the post of Chief Meteorological Officer, SHAEF (Air), was retained until May 1945. The location of the H.Q. in Paris enabled this officer to act also as a direct liaison between the Director of the Meteorological Office and the Director of the French National Meteorological Service.

With the defeat of the Allies on the continent in 1940, the Belgian Metorological Service was almost disbanded and only the Meteorological Institute at Uccle remained active, but on a purely scientific, non-operational basis only. The meteorological service for Belgian military forces had been militarised earlier and one senior member escaped to England where, as a R.A.F.V.R. Wing Commander, he made plans to create a nucleus of Belgian meteorological personnel, who might, on its liberation, be used in Belgium to assist in rehabilitation. He was in close liaison with D.M.O., and was available to assist in Belgium, when liberation came, with a small group of officers and men trained in the Meteorological Office.[1]

As soon as Brussels was occupied in September, the Chief Meteorological Officer 2nd T.A.F. interviewed the Director of the Uccle Observatory. There was promise that the Director might have arranged to set up civilian observing stations following the pre-war pattern, but the tentative plans made in England, vigorously pursued by the Belgian Wing Commander, made it necessary to go slowly. The Chief Meteorological Officer conferred with the Director of the Observatory and the Belgian Wing Commander, and the two Belgians agreed that it would be best to extend the meteorological service in Belgium by recruiting further Belgian nationals into the R.A.F.V.R., leaving the future of the civilian service to be decided when conditions were more settled. Enough personnel were already available to man one forecast section, and it was agreed

[1] A.M. File S.80863.

that, as far as possible, the airport at Evere, Brussels, should be manned by Belgians (R.A.F.V.R.). This arrangement, strongly sponsored by the Belgian Wing Commander, was perhaps not the best. There is no reason to suppose that difficulties of finance, recruitment, etc., would not have been overcome if a British Officer, representing the C.-in-C., had simply asked the Belgian Civilian Director to do all he could to co-operate on the basis of mutual aid. Instead, the existence and expansion of the Belgian Section of the Meteorological Branch of the R.A.F.V.R. put all the responsibility on the military authority and, in effect, side-stepped the re-creation of a Belgian Civilian Meteorological Service. However, the action taken was in accordance with the best Belgian advice available.

When Belgian nationals had been recruited in Belgium and trained in England, an observing network, independent of the military organisation but controlled by the Chief Meteorological Officer, 2nd T.A.F. was gradually established, with the forecasting office at Evere acting in the capacity of a Group or district centre. The unit at Evere, reinforced with British personnel, became a very active forecasting office for the main airport in Belgium. It was linked with the 2nd T.A.F. teleprinter network and functioned until late in 1945 as a unit within the British meteorological service. Re-establishment of a Belgian National Meteorological Service under Belgian control was thus deferred until after the war, but the Institute at Uccle was anxious to develop activities outside the military sphere. A British radio-sonde station, set up at Uccle in March, was soon brought into operation by Belgian civilian staff, and made an important contribution to the general effort.

As little of Holland and no part of Denmark was liberated until the final victory, it is only necessary to state here that immediately liaison was established with the national civilian authorities by the Senior Meteorological Officers of Nos. 83 and 84 Groups and later by the Chief Meteorological Officer personally who was in Copenhagen on 9 May and in Utrecht a few days later. In both cases, the national civilian meteorological authorities were enthusiastic to develop their services to meet all requirements, and the function of 2nd T.A.F. was largely confined to that of providing assistance and support in obtaining items of equipment, transport and communications. Progress was rapid.

Norway (May 1945–November 1945)

Plans had existed for some time before 1944 for the return of British forces to Norway. A joint Navy-Army-Air Force planning Committee had been formed with its headquarters at H.Q. Scottish Command, Edinburgh, the R.A.F. section having the designation of No. 13 Group (Plans). This committee produced the detailed plan and mode of operation. At first, the Meteorological Officer, H.Q. Scottish Command, was co-opted to the committee, but later the Meteorological Office was represented from H.Q.; after his appointment, the Senior Meteorological Officer of the force also attended. On 10 April 1945 No. 88 Group, R.A.F., was formed and took over the functions of No. 13 Group (Plans).[1]

The main features of the expedition were to be landings at six places, each with an attached airfield, by combined operations units (R.N., Army and R.A.F.) each of them self contained. The six airfields originally chosen were Oslo/

[1] A.S./312/M.O. 8.

Gardermoen, Stavanger/Sola, Kristiansand/Kjevic, Trondheim/Vaernes, Bardofoss and Kirkenes, but the last two were later omitted. Meteorological units were included in each of the four main parties, and the Senior Meteorological officer was responsible for meeting the meteorological requirements of the R.A.F. and Army units, and for securing adequate synoptic weather reports from Norwegian stations and transmitting them to the United Kingdom.

The R.A.F. component of the force consisted of No. 88 Group H.Q. with four Wings; the Group H.Q. were to be in Oslo and the four Wings at the four airfields viz. No. 128 Wing at Oslo, No. 129 Wing at Stavanger, No. 130 Wing at Trondheim and No. 132 Wing at Kristiansand. Meteorological provision consisted of a Type 1 unit for Gardermoen (Oslo), Type 2 units for the other Wings and a Type 4 unit for attachment to an Army Division to provide radar wind measurement for artillery Meteor reports and generally to cater for the Army's meteorological needs. The forecasting staff was to include officers with experience in Bomber, Coastal, Fighter and Transport Commands. All available Norwegian meteorological personnel were included and disposed so that at least one was available with each unit to act as interpreter. Certain experienced N.C.O. meteorological airmen from 2nd T.A.F. units and a small unit experienced in radar wind measurement by Army G.L.Mk.III equipment were earmarked for the expedition.[1]

As regards communications, it was planned that in the first stage of the landings each landing force would transmit hourly observations by point-to-point W/T link back to Rear H.Q. in the United Kingdom, and that each should receive throughout the 24 hours the ALFIG and BULFEX broadcasts from ETA, additional northern British stations being included.[2]

In the second stage, which would begin when the landing force at Gardermoen was established, it was planned that the Wings at Stavanger, Kristiansand and Trondheim would transmit hourly observations by W/T to Gardermoen at fixed times, and that Gardermoen would pass them by W/T to Rear H.Q. at Turnhouse, for transmission via No. 13 Group by teleprinter to ETA. At the same time, Gardermoen would transmit the reports to the forces in Norway. In addition, at a fixed time after each synoptic hour, an area forecast would be broadcast by Gardermoen for the benefit of the other British units in Norway. It was planned that at a later stage, the W/T link with the United Kingdom would be direct from Gardermoen to H.Q. No. 13 Group.

During 1944-45, it was not possible to concentrate the meteorological personnel and hold them in readiness, but when a signal was issued on 7 May 1945 that the operation was imminent, all personnel were concentrated immediately at R.A.F., Turnhouse, and all cases of equipment were sent at once to the dock designated for loading.[3]

The planned operations—Operation Doomsday—took place in stages between 8 and 27 May 1945. The Meteorological Office had not been given a clear indication of the association with the general plans of a scheme for a large number of airborne forces to be flown by No. 38 Group aircraft from E. England to Oslo on 9 and 10 May, and losses were suffered on the 10th as a result of flying into an area of bad weather of which little warning could be given.

[1] A.M. File A.782682/45. [2] A.M. File A.788840/45. [3] D.M.O./T.S.-4.

The Senior Meteorological Officer arrived at Oslo (Gardermoen) on 14 May and supervised the work of the German meteorological staff there. On 16 May, two airmen meteorologists arrived and took over the observational work from the Germans, and on 21 May the remaining staff allocated to Gardermoen arrived and replaced the German staff except the W/T operators. The staff allocated for the Type 4 unit were retained at Gardermoen until needed for duty with radar wind finding apparatus. Other British and Norwegian staff to man the Type 2 units arrived at Stavanger on 19 May, at Kristiansand on 24 May and Trondheim on 25 May. At first German staff were largely used for observing and meteorological communications duties under the supervision of British personnel, but they were replaced fairly quickly by British and Norwegian staff. On 19 June, the Senior Meteorological Officer, No. 88 Group, moved from Gardermoen to No. 88 Group H.Q. in Oslo, and set up his office there with a N.C.O. as administrative assistant. From then on, he attended the morning conferences of No. 88 Group Staff Officers.

Most of the transport to and from Norway used Oslo (Fornebu) airfield at which No. 163 Staging Post was located,[1] and flying boats used the adjacent fjord. No provision had been made in the original plans for this development, and the Commanding Officer No. 111 Wing represented that no British meteorological advice was available at Fornebu. The Senior Meteorological Officer No. 88 Group visited the station on 5 June and found that the local meteorological office had been taken over by the Norwegian Meteorological Institute for just over a fortnight. Although there were two civilian Norwegian forecasters there, the three German forecasters were doing most of the forecasting. It was arranged for the German forecasters to be withdrawn in a few days and for a Norwegian forecaster, with one British N.C.O. and three airmen meteorologists to be temporarily attached to Fornebu. The British N.C.O. acted as liaison officer and interpreter in obtaining meteorological information from the Norwegians. On 27 June 1945, the N.C.O. and airmen at Fornebu, with one British and one Norwegian forecaster, were transferred to Bardofoss where No. 170 Staging Post had been opened, in order to ensure that British aircrews were briefed by British and Norwegian personnel. One German forecaster was, however, held temporarily at Bardofoss to act as interpreter and to help with routine work. Another N.C.O. was posted to Fornebu to replace the staff going to Bardofoss and to act as permanent liaison with the Norwegians.

Arrangements were made on 24 June for the issue of landing forecasts for Fornebu in 'PROG' code. These were transmitted from Gardermoen to No. 13 Group and thence by meteorological teleprinter to ETA. They were also passed via No. 163 Staging Post Signals to H.Q. No 46 Group.

A small R.A.F. meteorological unit was opened on 14 July at Bergen for liaison duties at the Norwegian Meteorological Institute there. It assumed responsibility for supplying forecasts for the R.A.F. on 23 July. An American A.T.C. Weather Office was opened at Gardermoen in July but all forecasts for the American aircraft were provided by the British office.

Nos. 149 and 540 Squadrons (Lancasters) R A.F., based on Trondheim, carried out an extended photographic survey of the northern half of Norway

[1] A.M. File A.782682/45.

in August and September 1945. Full briefings were provided by the local meteorological office, and it was arranged for the ALFIG upper air bulletin to be extended to 74° N. in Norway.

Preparations were made during September and October for the final withdrawal of British meteorological personnel from Norway. The meteorological office at No. 170 Staging Post, Bardofoss, was handed over to the Norwegians on 26 September, and some of the British staff left for the United Kingdom on 7 October. The staff with No. 132 Wing, Kristiansand left on 28 October, and the staff with No. 130 Wing, Trondheim, and No. 129 Wing, Stavanger, left during the first fortnight in November. The British meteorological office at No. 28 Wing, Gardermoen, closed on 14 November and the Senior Meteorological Officer, No. 88 Group, left Oslo for the United Kingdom on 17 November. On 21 November, No. 88 Group closed in Norway and re-opened at R.A.F. Station, Dunsfold, in the United Kingdom. A British Meteorological Liaison Officer stayed behind in Norway at Oslo (Fornebu) for a few months longer, particularly for duties at the R.A.F. Staging Post.

Communications

The German meteorological communication network was taken over intact by the British forces and was used as a basis for the British system ; the main teleprinter centres were at Morn, Trondheim, Bergen and Oslo. At these centres, reports from Norwegian stations in the area were collected, mainly by telephone or by wireless when telephone communications were bad. These local collectives passed by telephone to Holmenkollen although the teleprinter could be used for this purpose where there was a two-way channel. Holmenkollen then broadcast the completed collective message by teleprinter to all stations. On 2 June 1945, the A.O.C. No. 88 Group, informed the Joint Signals Board, Oslo, that the existing meteorological teleprinter network should be retained for the time being under the control of the R.A.F. During June, a start was made in setting up a parallel system to the German network centre at the Norwegian Meteorological Institute, Blindern, but the latter did not take over the network completely until 15 September, when the old German H.Q. at Holmenkollen was closed. The German Luftwaffe and Naval meteorological wireless organisation was also used.[1]

Meteorological information was received at No. 88 Group Meteorological Office, partly by the German teleprinter network and partly by wireless. The organisation for obtaining reports from the British units had been described in the paragraph dealing with planning. The second stage in the signalling plan was in operation by 22 May 1945. For the first two weeks of September, the Blindern (Norwegian) and Holmenkollen (German) teleprinter networks operated in parallel, but on 15 September, the German H.Q. at Holmenkollen was closed and the teleprinter broadcast was centered wholly at the Norwegian Meteorological Institute at Blindern.

From 22 May, Oslo (Gardermoen) began to transmit an hourly collective of Norwegian synoptic observations primarily from No. 88 Group stations, but including also any other Norwegian reports available. The reports were received at H.Q. No. 13 Group by wireless and were passed from No. 13 Group

[1] A.M. File A.788840/45.

meteorological office to ETA by meteorological teleprinter. Gardermoen hourly observations also were passed to No. 38 Group meteorological office by the No. 38 Group Signals Unit in Norway.

On 1 August, the Norwegian Meteorological Service resumed meteorological broadcasts from the Oslo high power transmitter LCH on a frequency of 5,505 kc/s per second at HH plus 20–25 and HH plus 40–55 where HH = 03, 06, 09, 12, 15 and 17 hours G.M.T. The resumption of the broadcasts on this frequency was approved by the British Joint Communications Board.

The main sources of overseas data for the British units in Norway were the ALFIG and BULFEX messages, but meteorological broadcasts were also received from Denmark and Sweden.

Upper Air Information[1]

On the arrival of British Forces in Norway in May 1945, it was found that the Germans were making radio-sonde ascents twice daily at Bergen, Kjeller, Rognan, Bardofoss, Trondheim and Kristiansand. During June, the radio-sonde ascents were reduced to one daily at each station at 0500 B.S.T. in order to conserve equipment. On 3 July, the Germans were instructed to close the radio-sonde stations at Kristiansand and Rognan.

A Norwegian Meteorological Officer and a N.C.O. were sent to Bodo on 24 July, to open a Radar wind-finding unit, using G.L. III equipment and to supply Meteor reports to the first Norwegian Heavy A.A. Brigade at Bodo, but before all the required equipment had arrived, the A.A. Brigade moved south. The meteorological staff were withdrawn to Oslo for eventual transfer to Tjole, the new destination of the Norwegian Brigade, but here again, all equipment was not received in time for the unit to operate under British auspices.

Arrangements were made in July 1945 for the supply of meteorological instruments for use by Spitfire aircraft of No. 331 (Norge) Squadron at Gardermoen to observer upper air temperatures, but these 'Thum' ascents were not begun until 2 August. The ascents reached 15,000 feet only, and were very irregular, partly because of restricted control facilities and partly because of bad weather.

Gradually, Norwegian staff were trained in radio-sonde work and became available to replace German personnel. By early September 1945, Norwegians were ready to take over completely from the Germans the radio-sonde station at Kjeller; at Trondheim Norwegian staff were partly trained, and training had begun at Bergen. It was due to start soon at Bardofoss. The Norwegian plan was to have, eventually, radio-sonde ascents at Oslo, Kristiansand, Bergen, Trondheim, Thomso and Jan Mayen. From 18 October, a radio-sonde ascent was made twice daily at 0500 and 1700 hours G.M.T. at Gardermoen by a unit of the American Weather Office; this unit also made radio-wind observations from 24 October; the observations were included in the No. 88 Group broadcasts.

Proposals were made in August for four navigators of the Royal Norwegian Air Force to be trained in the United Kingdom as Meteorological Air Observers, preparatory to beginning a meteorological reconnaissance flight from Trondheim towards Iceland.

[1] A.M. File A.788654/45.

German Meteorological Organisation in Norway[1]

The German Meteorological Service with the Luftwaffe in Norway in May 1945, consisted of 396 officers and men with equipment and facilities equivalent to a Headquarters (Holmenkollen) plus ten Type 1 units, fourteen Type 2 units and three radio-sonde units. As regards the German Naval Meteorological Service, there were 80 officers and men spread over nine offices with equipment and facilities equivalent to two Type 1 units, seven Type 2 units and four radio-sonde units. In the initial stages of the campaign, some use was made of the personnel of the German organisations, but they were gradually replaced by British and Norwegian meteorological staff. At Oslo (Gardermoen) after 22 May 1945, the only German staff retained for meteorological work were three Wireless Operators. At Trondheim (Vaernes), all German meteorological staff except Wireless and Teleprinter Operators were removed by 11 June. At No. 163 Staging Post, Fornebu, all German meteorological staff had been replaced by Norwegian civilian and service personnel plus a small party of R.A.F. airmen meteorologists by the end of the first week in June. At Stavanger (Sole) the meteorological office was also manned completely by R.A.F. personnel by 7 June. No, 170 Staging Post (Bardofoss) was manned by British and Norwegian staff from 27 June, but one German forecaster was retained temporarily to act as interpreter.

As a result of the decision of the A.O.C. No. 88 Group that all Germans in northern Norway were to be evacuated by the middle of September, the German radio-sonde staff at Bardofoss were replaced by Norwegian personnel from Kjeller and, consequently, the staff at Kjeller was temporarily completely German. On 28 September, all German Air Force personnel were removed from the Meteorological Institute, Bergen, except for one teleprinter mechanic.

It was agreed on 26 October 1945, that a small nucleus of the German Naval Meteorological Service should be allowed to remain in Norway until the spring of 1946, to supply forecasts to German personnel for minesweeping operations. It was also agreed that the meteorological transmitter PZU at Trondheim should continue to be manned by German operators.[2]

Although the provision of meteorological equipment for the British meteorological units had been arranged before they went overseas, it was found possible on arrival in Norway to use most of the German meteorological equipment; the British equipment was, therefore, held in reserve. During June, meteorological stores originally intended by the Germans for opening two new stations in Greenland, were found near Trondheim. Detailed lists of G.A.R. meteorological equipment in Norway were compiled and a certain amount of the equipment was handed to the Norwegian Meteorological Service. Lists of all such equipment and particulars of its disposal, were passed to the Chief Meteorological Officer of the Control Commission (Air Division) British Element, B.A.O.R., and on 20 August 1945, the Senior Meteorological Officer, No. 88 Group, was authorised by the Control Commission to dispose of all German meteorological equipment; this was distributed between the British and Norwegian Meteorological Services in Norway.

[1] A.M. File A.782682/45. [2] F/C.30/M.O.8.

Liaison with Norwegians

Throughout the operations, close liaison was maintained with the Norwegian authorities. Several Royal Norwegian Air Force meteorological personnel were included with the British Forces landing in Norway, at least one being allocated to each unit to act as interpreter. Dr. S. Petterssen, who had been acting as Head of the Upper Air Branch of the Central Forecasting Office, accompanied the Norwegian Forces and acted as liaison officer with the Norwegian Meteorological Institute.[1]

On 16 May 1945, the Senior Meteorological Officer, No. 88 Group, and Dr. Petterssen, visited Dr. Bjorkdahl, the Deputy Director of the Norwegian Meteorological Institute, to discuss communications and means of getting the Oslo LCH transmitter working. On 25 May, they discussed codes and provisional arrangements for handing over the German meteorological teleprinter system to the Norwegians. On 9 June, another meeting was held at the Norwegian Meteorological Institute, Blindern, at which Dr. Hesselberg, Director of the Norwegian Meteorological Institute, presided. It dealt with a wide range of current problems including staffing, radio-sonde ascents, meteorological codes, etc. Dr. Hesselberg did not wish to change the Norwegian practice of reporting at 0700 and 1700 G.M.T. to the standard hours of 0600 and 1800 G.M.T. respectively, owing to the difficulties of communications in the early morning and evening. It was arranged to use the Combined Analysis Code throughout Norway. At a meeting on 3 July, it was planned to post four W.A.A.F. meteorological N.C.O.s to Blindern to help the Norwegians in running their communication organisation. The W.A.A.F. N.C.O.s were volunteers and were given instruction at the Central Forecasting Office before being posted. On arrival in August, they supervised the reception and broadcast of all information by teleprinter and wireless. On 18 July, 18 Norwegian forecasters were distributed for training among the No. 88 Group meteorological units and on 30 July, 30 Norwegian meteorological assistants were also posted to the No. 88 Group stations.

Close liaison was maintained with the Norwegians in regard to the supply of instruments and equipment, and some German equipment was handed over to them. When the British units withdrew, the British equipment, and spares for the Spitfire meteorological ascent and a quantity of the British radar wind equipment used for a wind-finding unit, were handed over to the Norwegians.

[1] A.M. File A.782682/45.

CHAPTER 15

METEOROLOGICAL SECTION, AIR DIVISION, CONTROL COMMISSION FOR GERMANY (September 1944 to March 1946)

When it seemed that the Allied armies might drive through the Low Countries into the North German Plain in the autumn of 1944, the nucleus of an Air Echelon of the Control Commission was hastily formed. At that time, service ideas on how the war with Germany would end were numerous and diverse, the most prevalent being that the Germans would seek an armistice while the Allied troops were still west of the Rhine and that the war would end with the German forces still fairly well organised. On this basis, the primary functions of the Meteorological Section of the Air Division at that stage were broadly :—

(*a*) To prepare a plan for the overall control of the meteorological service in Germany.

(*b*) To collect all the latest available information about the organisation of, and main personalities in, the German meteorological service.

(*c*) To practise techniques for dealing with high ranking enemy officials under various assumptions of subtle evasion, non-co-operation and wilful obstruction in the early stages of control.

The arrangements approved by the Director of the British Meteorological Office and the Air Division for the early stages of Control envisaged the formation of German meteorological organisations in each Zone of Occupation. These zonal organisations would be the smallest necessary for meeting allied meteorological needs in each zone, for meeting allied needs for internal air traffic and general synoptic purposes and for meeting the needs of the Central Allied Control authorities. From the outset, the organisation in each zone would be designed to facilitate centralisation of some of the less potentially harmful activities of a meteorological service, such as the making and collection of climatological observations, which did not need a telephone or teleprinter network to be operated by German personnel. In the first stages, only assistant personnel from the former German Meteorological Service would be employed ; where employed for making synoptic observations, they would not have access to centres or sub-centres of the meteorological telephone or teleprinter network in the zone. A Four-Power Meteorological Committee under the Control Council would be responsible for decisions on general policy in developing these nuclei of German zonal organisations ; the Chief Meteorological Officers of the occupation Forces would execute the policy and supervise its effects. The Meteorological Committee of Control would recognise the ultimate need to centralise administration of the separate organisations so as to ensure equivalent conditions of service, rates of pay, etc., for the Germans employed ; it would also ensure zonal interchange of meteorological data by making every effort to introduce common reporting codes, forms for meteorological returns, etc., for use in all zones. It would advise the Control Council on how to achieve these ends and on the dates when stage-by-stage centralisation could be effected.

Any plan that was adopted would need to conform to the general policies of inter-allied control, and so could not be used as a basis of working in any one zone until approved by the meteorological Control representatives of the four occupation powers and authorised by the Inter-Allied Control Council. Copies of the British plan for meteorological control in Germany were sent to the U.S. and French meteorological authorities and the Director of the Meteorological Office tried, through the British Foreign Office to arrange a meeting with Russian meteorological representatives. By the time the British plan had been drawn up and agreed by all British authorities (October 1944), it was clear that the Control Commission would not be called into action for several months.

The Advanced Echelon of a Control Group, including the Chief Meteorological Officer's team, moved to Paris (St. Cloud) on 10 May, ready to be called forward into Germany as suspected 'targets' were uncovered by the Allied Forces. Daily conferences were held to hear reports from advanced intelligence sources, and decisions on sending forward advance-parties were made on these reports. It was learned on 19 May that an important meteorological target had been found, with others, at Berchtesgaden, and the Chief Meteorological Officer was put in joint charge of a party of about twenty Air Division Officers which was sent there on 21 May. On arrival, the party found that security officers on the spot had banned interviews with the German officials concerned who included the Chief of the German Weather Service and some of his H.Q. officials. Despite representations through high-ranking officers of the appropriate SHAEF branch, the British contingent had to return to Paris without an opportunity of interviewing the Germans.

Before the Air Division moved into their German H.Q., the British Meteorological Control Officer began meetings in Paris, with his opposite numbers in the U.S. and French Meteorological Services, at which the British Meteorological Control plan for Germany was used as the basis of discussion with a view to clearing the ground for the ultimate quadripartite meetings in Germany.[1] The French and American representatives accepted the British plan although care was taken not to make any formal agreement which might have prejudiced the four power discussions at a later stage.

When it became clear that conditions in Germany had rendered valueless for Control purposes any working remnant of the German war organisation, there was a period of uncertainty and indecision. Although the Meteorological Section of the Air Division had plans for coping with this kind of contingency, and were probably unique in having prepared the ground for immediate quadripartite talks, the Air Division was not transferred to Germany (Detmold, Lippe) until early July 1945. During this period, and for the next two months, priority facilities for proceeding with Control plans was given to the Communications, Transport and Food and Agriculture Divisions of the Commission; the Meteorological Section had to be content with collecting information from British and U.S. sources about the distribution of German meteorological personnel, equipment and records. After many false starts, it was agreed on 24 August that the Meteorological Section of the Air Division should be represented at the first of the quadripartite meetings on Air Matters in Berlin.

[1] In addition to the efforts made by the D.M.O. at an earlier stage to arrange similar discussions with U.S.S.R. meteorological representatives, SHAEF channels were used at this stage to achieve the same end but without success.

At that meeting, on 27 August, the Air Directors of all four Powers agreed that a Meteorological Control Committee should be formed with a view to making recommendations on how German meteorological personnel could be used to meet Allied needs in Germany. Because of French and American difficulties in providing meteorological representatives in Berlin, the first meeting of the Committee, attended by representatives of all four Powers, was not held until 17 September 1945.

Quadripartite Meetings

From the time of the first meeting, the Chief Meteorological Officer, Air Division, attended weekly four-Power meetings in Berlin, returning to Detmold between meetings for policy discussions with other branches and with the Chief Meteorological Officer, British Air Forces of Occupation (B.A.F.O.) As in all quadripartite meetings of the Control Commission, the chief representative of each country took the chair in turn for a month, during which he had the initiative in preparing the agenda and so guiding the Committee along lines which he wished discussed. Each representative had two interpreters provided from a pool in his own Directorate. No proposal could be adopted by the Committee unless agreed by all four representatives. One Secretariat served the various Committees under the Air Directorate and all recommendations from Committees had to be submitted to the Air Directorate. If the Air Directorate approved, on briefing by their representatives on the various Committees, the findings were passed to the Executive Committee of the Control Council for final authority.

Difficulties in interpreting made Committee meetings normally slow action affairs. Any real coherent and close discussion was impracticable; only basic matters expressible in simple non-technical language which the interpreters could understand, could be handled. Even then, discussions often continued for stretches of six to eight hours without a break. The various stages through which a unanimous four-Power recommendation of the Committee had to pass before action was authorised led to further complications especially when technical subjects like meteorological re-organisation were handled by non-meteorological service officers. Misunderstanding between any one of the four members of the Committee and his Service Chief at the Directorate level, mistranslation in any one of three languages of a technical phrase in the documents prepared afresh for consideration at each higher level, use of the same word in different senses by the various countries, changes of mind by a committee member between the time he agreed to a proposal in Committee and the time he briefed his Chief on the attitude to be taken in discussion at the next level, all caused action to be suspended for weeks. Even when the final authority returned to the originating committee, it might be so circumscribed by caveats entered by any one of the four Generals at the Control Council (Executive Committee) stage or by the next in succession at the Air Directorate level that it had lost its original significance. The Committee could then only start afresh with new recommendations at Committee level.

An unexpected feature of the work of the Meteorological Committee was the fundamental difference between the attitudes of the four delegations to important matters. Discussion was coloured less by what some delegates knew to be technically sound than by what they considered their non-meteorological chiefs at high levels of Control would expect of them. In January 1946, one

delegate turned down one proposal after another whenever the words 'future of eventual centralisation' occurred, even though he had earlier agreed that ultimate centralisation of a limited number of the functions of the German Service was one of the Committee's aims, and even though it was realised that any step towards centralisation would have to be authorised by the Control Council.

The Meteorological Committee's Work (September 1945 to March 1946)

The first step was for the Committee to adopt one broad plan for the early stages of control. Ideas had changed somewhat since the talks between British, U.S. and French meteorological representatives and their informal acceptance of the British plan, international politics and particularly the Three-Power Potsdam agreement, made without French participation, had worked in opposite directions with the U.S. and French representatives. Nevertheless, all four delegates agreed to adopt the British plan as a basis of discussion, but whereas the U.S. delegate was open to consider its implications as regards future partial centralisation of administration of the four separate zonal services within the framework of general control, the French would not contemplate any such possibility even as a matter of wording. The Russian attitude was between the U.S. and French. After two meetings, the Committee adopted the British plan largely as it had been originally framed.

After September, the chairmanship passed from the British delegate in turn to the French, Russian and U.S. delegates. Instead of proceeding to fill in the details of the broad plan of meteorological control as approved by the Air Directorate, the Committee was obliged to consider French proposals for such matters as the recovery and restoration to France of meteorological equipment of French origin found in any zone of occupation and the allocation to France of surplus German meteorological equipment. The Russian delegate produced in November papers defining the several categories of German meteorological personnel to be employed in the zonal organisations and their scales of pay. He was also concerned about using the Committee as a clearing house for the interchange of technical documents between the German meteorologists working in the various zones. In December, with the U.S. delegate in the chair, the committee was asked to consider U.S. proposals for an exchange in committee of detailed reports from each delegate on the state of the zonal organisations, and early centralisation of the administration of the organisations. The first of these proposals was eventually adopted, the second was rejected as premature.

During January 1946, under the chairmanship of the British delegate, the papers laid before the Committee included proposals for uniformity of times and procedures for climatological and synoptic observations throughout Germany, for new terms of reference for the Committee, for facilities for zonal interchange of German meteorologists, for arrangements for interchange of correspondence of scientific matters between German meteorologists in the four zones and for the broad structure of the German organisation in each zone. This last paper, a sequel to the Committee's adoption of the British plan of control, set out the maximum number of allowable branches of each organisation, the nature of the work permitted and the means of administration. It was designed to facilitate future merging of the organisations when approved by the Control Council by ensuring that the separate organisations were being constructed on broadly

similar lines and with corresponding branches having similar well-defined functions within the general framework of control. All the papers put forward in January were adopted, except the last, on which discussion was only started. Discussion on these British 'structural' proposals was completed at the end of March with the adoption of the paper almost as first submitted.

The French chairman unexpectedly proposed in February to centralise in Berlin the broadcasting of synoptic data from all zones. The U.S. delegate endorsed the proposal as it was in keeping with his attitude of wholesale centralisation even while the zonal organisations were just being formed. The Russian delegate also supported it, probably because it ensured that all synoptic material would be fed into his zone. The British delegate agreed on the practical need to collect synoptic material from all zones at one place and to broadcast it by radio and teleprinter to other centres, but he could not agree that the perpetuation of Berlin as a central European collector and distributor of data was sound Control policy. This, and other matters about which one or more members of the Committee could not agree, were referred to the Air Directorate for guidance.

The Russian delegate proposed and the Air Directorate agreed that the Meteorological Control Committee should represent Germany at the London Conference of the International Meteorological Organisation in February–March 1946, and the French and British delegates attended the conference. The Russian delegate was to have attended but was detained in Berlin. The delegates reported on the state of re-establishment of the German meteorological service in each zone and supplied information on such matters as the distribution of copies of German meteorological publications, and the channels for recovering equipment alleged to have been removed from occupied countries.

It was decided at the end of March 1946 that the basic policies for meteorological control had been established enough for the posts of Chief Meteorological Officer (Control Policy) and Chief Meteorological Officer (Occupation Forces) to be combined. The Chief Meteorological Officer (Control Policy) was withdrawn and the Control aspect of the meteorological work in Germany became his deputy's responsibility.

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Throughout the intermittent association of the Meteorological Section with the Air Division, energies often seemed to be fruitlessly spent, but it is difficult to see how else matters could have been handled in view of the doubts on how the German collapse would come about and the state of organisation or otherwise in Germany, and of the fact that the Meteorological Section was an integral unit of a Service organisation rapidly built up to deal with Control problems with which few people had had experience. It was unfortunate from the meteorological viewpoint that control was effected through a Service organisation, for while the Service Divisions of the Control Commission were primarily concerned with making it impracticable for the German war machine ever to work again, the Meteorological Section had far more in common with some of the civilian divisions such as Transport, Communications, Food and Agriculture, whose main task was to restore such order as was needed to meet Allied Control aims by re-establishing adequately supervised German

organisation and services. Believing that a meteorological service exists only to meet military needs, senior Service officers were not always able to appreciate the Meteorological Section's wish to rebuild a German meteorological organisation when they were trying to destroy every trace of the former war machine. This difficulty might have been eased if those Branches of the Service Divisions which needed to plan along different lines from their parent Division had been able to consult with the Branches of the Civil Division with whom they had more in common. For example, the policy for reconstituting a German meteorological organisation to meet allied needs had probably much in common with that for reorganising the German railway and transport system of postal services. Unfortunately, however, the Civil Divisions were much slower in forming than the Service Divisions so that the Meteorological Service was denied contacts which might have proved useful. The resulting uncertainties were not decreased in Germany when the Air Division formed its base H.Q. away from those of other Divisions. Outside the Air Division itself, contacts were never easy.

Although the Air Division would probably have vetoed the arrangement, it might have saved staff and led to closer and more effective co-operation, especially in the first days of occupation, if a senior officer under the Chief Meteorological Officer in the Field (at first 2nd T.A.F. and then B.A.F.O.) had been deputed to act for him in Control affairs. As he was already responsible for 'disarmament,' he might then have had a clearer picture of how this phase was related to ultimate control policy, and the later phase of carrying out in the field the general policy agreed by the Quadripartite Control Committee might have been more acceptable.

CHAPTER 16

GOVERNMENT DEPARTMENTS AND ESSENTIAL SERVICES

Fog Dispersal Work (Fido) for Ministry of Fuel and Power

Experiments were made at Farnborough in the winter of 1938–39 to examine the practicability of dispersing fog by means of heat supplied by oil burners. The Meteorological Office was associated with these trials and steps were being taken to increase the scale of the experiments when the outbreak of war led to their termination as a quick solution appeared impracticable. A summary of the work on the problem in the United States was prepared for the Aeronautical Research Committee in the autumn of 1941, as there were signs of a renewal of interest in the subject, but it had already been decided that the prospects of success were not good enough to justify continuing the experiments. Finally, in October 1942, the problem was revived as a matter of great urgency and importance, and the Petroleum Warfare Department of the Ministry of Fuel and Power was made responsible for pursuing the matter. Following preliminary discussions between that Department and the Meteorological Office on the technical aspects of the problem, a Meteorological Officer was posted to the Petroleum Warfare Department (P.W.D.) to advise and assist the P.W.D. on the meteorological aspects of fog dispersal. Other meteorological staff were posted later as the development of work demanded. Arrangements were made for the supply of forecasts of fog formation at various airfields and for special meteorological observations at operational airfields during the operation of fog dispersal apparatus. The meteorological section at H.Q. P.W.D. was disbanded in October 1945.

The problem, as laid down by the Air Staff, was to clear from fog to a depth of about 100 ft. a fixed runway, approximately 1,000 yards long by 75 to 100 yards wide.[1] It was agreed that only the type of fog associated with clear calm nights, *i.e.* radiation fog, need be considered. From the outset, the main effort was concentrated on clearing the fog by supplying to the atmosphere enough heat to evaporate the fog droplets and to reduce the relative humidity of the air from 100 per cent. to 90 per cent. The meteorological aspect involved two problems: the available information concerning the size of fog droplets and the amount of liquid water suspended in a fog was inadequate, and the distribution of heat from a long line of burners operating in the weather conditions associated with fogs was not known.

Of the above two problems, that relating to the structure of fog was pursued with little success until March 1944, the difficulty being in designing suitable apparatus to measure drop sizes and water content. In March 1944, new types of apparatus were used for both these measurements with appreciably more success than before, and from then until the disbandment of the Meteorological Section as associated with this work, many measurements of drop size and liquid water content in fog were made. From the purely meteorological aspect, much remains to be done on this subject but the results

[1] A.M. File S.84807.

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obtained during the work referred to above confirmed in broad outline, the information available in 1942 and established that the attack on the problem of evaporating the fog droplets was proceeding on the right lines.

The problem of the distribution of heat in the atmosphere from a long line of burners placed along the ground could be tackled in several ways. A purely theoretical approach alone seemed unlikely to be adequate, so the P.W.D., in collaboration with the National Physical Laboratory, organised small scale model experiments in a wind tunnel. As such work needs full scale confirmation, a large number of full scale experiments were made in an unfinished reservoir at Staines. Foggy conditions were not needed to carry out these trials; when the temperature structure of the lower atmosphere was similar to that normally experienced in fog, one or more lines of petrol burners about 650 yards long was ignited and the temperature and wind speed measured at various heights and distances down wind from the burners. Comparison of these measurements with similar measurements made immediately before and after ignition of the burners showed the effect of the supply of heat upon the temperature and wind distribution. From a knowledge of the constitution of a fog it could then be estimated whether the fog would in fact have been dispersed had it been present before igniting the petrol. The rate of supply of petrol to the burners could be varied so that the minimum fuel consumption for effective fog dispersal could be determined. Experiments of this type were begun in December 1942 and the first series was completed in the following January. Similar experiments under foggy conditions were started in January 1943.

Practical Problems

It was realised from the start that the effect of fog dispersal apparatus would depend upon the wind speed and the direction of the wind relative to the runway. Early experiments used two long lines of burners which were visualised as being installed on either side of the runway. It soon became clear that one of the major problems was to prevent intrusion of the fog at the ends of the runway between the burner lines, and experiments were made with various dispositions of short burner lines to 'seal' the ends of the cleared runway against this fog intrusion. Another problem, which had not been clearly foreseen, arose from the fact that when the wind speed above the top of the fog was not small, the wind speed at the surface increased on ignition of the burners, thus dissipating the heat more rapidly than was desirable.

Throughout the work, the experimental layouts of burner lines had to be related to the practicability of aircraft landing between the lines of burning petrol. There was also an obvious need to find a solution which was most economical in the use of fuel, consistent with achieving the required result. By August 1943, a practicable solution had been found, one airfield had been equipped and equipment was being obtained for installation on seven other airfields. Of these seven airfields five were in operation by December 1943. It was arranged in February 1944 to equip a further seven airfields. During this period, while airfields were being supplied with this apparatus and subsequently used for landing aircraft under foggy conditions, experiments were continued to determine the effect of different wind directions relative to the runway especially with a view to determining the minimum fuel requirements.

From the time the first airfield was equipped to the end of the European war, fog dispersal equipment was used to assist aircraft landing on 117 occasions when visibility was less than 500 metres, 306 aircraft being involved, and on a further 44 occasions with visibility between 500 and 1,000 metres, 416 aircraft being thus enabled to land safely.[1]

Smoke Screen Work for Ministry of Home Security later War Office

The problem of protecting vital areas by smoke screens had already been studied by the Chemical Defence Research Establishment at Porton when, on 28 May 1940, the Prime Minister directed that a Committee be set up to review the question of smoke screens to hide factories from aerial attack. Following this Committee's report, the Ministry of Home Security set up the necessary organisation to take exclusive control of all measures for providing smoke for purposes of protecting vital industrial establishments. The problem of producing smoke screens was defined by the Smoke Committee as the production of haze dense enough to obscure targets on moonlight nights and large enough to make aimed bombing of targets impossible. Various methods of achieving this were considered but the only method which involved the direct application of meteorological knowledge, and the one which eventually justified the greatest expenditure of effort, was the use of special smoke generators.

The first test of the use of modified oil-burning orchard heaters to produce the smoke was made at Sterartby, near Bedford, on 20 June 1940, when the moon was full. Conditions were typical of a clear summer night with a light irregular wind and the meteorological problem of forecasting the wind direction was exceptionally difficult. This trial was inconclusive as there was some general ground haze which made it difficult for the observing aircraft to decide how much of the obscuration was due to the artificial smoke screen, but it confirmed that the problem of screening factories from aerial attack was being tackled on the right lines. Preparations were accordingly made to adopt smoke screening at a number of important industrial plants.

At the beginning of these operations it was intended to use smoke screens during that part of the night when the moonlight exceeded a certain value, provided the forecast indicated less than ten-tenths of cloud below 5,000 feet.[2] The screen would not be operated if the wind exceeded a certain value (approx. 25 m.p.h.) as the screening would then be ineffective. In detail, these requirements were modified later, but the broad picture remained the same. Smoke screens were most necessary, of course when the sky was clear and moonlit, on which occasions the surface wind is often light and the direction of the wind is difficult to forecast. Moreover, smoke streamers from individual smoke generators normally form narrow ribbons under such conditions. With these considerations in mind, the early plans visualised a circuit of smoke generators surrounding the factory to be screened. The generators would be more or less evenly spaced and only a few would be ignited on any one occasion. The number of generators ignited would depend on the accuracy with which the wind direction could be forecast, and the precise arc selected for ignition would be determined by the forecast wind direction.

[1] The meteorological aspects of fog dispersal have been discussed in two reports, viz.: Petroleum Warfare Department Report No. 5F (also issued as Synoptic Divisions Technical Memorandum No. 55) and Synoptic Divisions Technical Memorandum No. 112, issued by the Meteorological Office.
[2] A.M. File S.61501.

The tendency of smoke trails to be narrow under those conditions when screens were needed, affected the spacing of the generators as it was clearly essential for the trails from neighbouring generators to join up before the smoke reached the target. This was also the major factor in determining the radius of the circuit, as the travel of the smoke had to be long enough for the cloud to spread. As the minimum radius for this purpose was of the order of 1,500 yards, and the smoke screen was not easily recognisable from the air at night, there was little danger of the enemy pin pointing the target by means of the screen. To provide for occasions of light variable winds with no definite wind direction, radial lines of generators extending outwards from the target as centre were planned. Another meteorological factor of importance at individual airfields was that on clear nights smoke does not rise very readily. It will, in fact, flow round a tall isolated obstacle rather than over it.

In practice, a compromise was necessary between the ideal layout of generators and practical requirements such as the need for the generators to be placed where they could easily be serviced and refuelled. Normally this involved placing them on a road. Thus the circuit was usually a very imperfect circle with the spacing of the generators along any road being adjusted to give the theoretical spacing in the direction of the ideal arc at that point. Superimposed on these theoretical and practical considerations was the obvious need to give due attention to the need for economy in oil fuel and operating personnel.

Meteorological Organisation

Following the decision to proceed with smoke screening operations, an initial list of factories needing such protection was drawn up and Local Control Officers appointed by the Ministry of Home Security. The first sites chosen were at Derby and Crewe. At first, the list of sites grew fairly rapidly as facilities for screening became available. Later, the list became more or less stabilised until shortly before D Day.

Under conditions of clear skies and light winds, the wind regime in any particular locality is greatly influenced by local topography. It was accordingly decided to attach one or two meteorological officers to each site, or group of sites when more than one site was located in close proximity. These officers received advice regarding the general meteorological situation from the most convenient existing forecast centre, and on the basis of this advice and of the experience of local conditions as time went on, the meteorological officer advised the Local Control Officer on which generators should be ignited to provide a smoke screen in the weather conditions expected during that night.[1] Meteorological assistants were also attached to each site to make observations of meteorological conditions during the night. These observations were needed in view of the importance of local conditions. As the number of screens grew, it became more possible to group several screens together from the point of view of meteorological advice and to make one meteorological officer responsible for advice covering the group of screens. In addition to the local meteorological staff attached to each site, a meteorological section was posted to the appropriate Division (L.4) at the Ministry of Home Security.[2] The functions of this section were to administer the meteorological staff attached

[1] Synoptic Instructions—Special No. 2.

[2] A.M. File S.61501.

to the various smoke screens and to provide meteorological advice to the Ministry of Home Security. As additional factories were chosen for screening, it became necessary to draw up detailed plans for the siting of the smoke generators. A detailed plan for the placing of generators was usually drawn up by the meteorological staff at L.4 Division from an examination of large scale maps. Subsequently one of the meteorological staff would visit the site in company with a representative of L.4 Division to confirm or modify the plans. Throughout the period during which smoke screens were used, the layouts were being modified more or less continuously either to economise in fuel or manpower or to take advantage of new types of generators or of the mounting store of experience.

The War Office took over on 1 April 1943 the administrative responsibility for Smoke Protection Work previously held by the Ministry of Home Security, and the meteorological staff previously attached to L.4 Division were then attached to H.Q. Anti-Aircraft Command. The meteorological officers attached to groups of sites were gradually transferred to the appropriate A.A. brigades.

During the summer of 1943, proposals to replace the meteorological assistants at smoke screens by suitable trained Pioneer Corps N.C.O.s were discussed with H.Q. Anti-Aircraft Command. Eventually, four training courses were held between October 1943 and September 1944, at the Army School of Chemical Warfare, and as the Pioneer Corps N.C.O.s became qualified, they replaced the meteorological assistants at the smoke screens.

From June 1944 onwards, the various smoke screens in Great Britain were gradually closed down, the last one being discontinued in September 1944. The last member of the meteorological staff at H.Q. Anti-Aircraft Command was posted away in January 1945. The growth and subsequent diminution of the organisation outlined above can be assessed from the following figures :

Date	*Meteorological Staff*	*Screens*
July 1940	27	10
Dec. 1940	22	9
June 1941	33	20
Dec. 1941	44	26
June 1942	54	31
Dec. 1942	59	31
June 1943	56	27
Dec. 1943	47	21
June 1944	25	14
Dec. 1944	3	0

Developments in Technique

Reports by R.A.F. pilots on the efficiency of the screens operated during July 1940 were not altogether favourable, and in August and September 1940 further aerial observations were made by Meteorological Office Staff. It was then considered necessary to carry out an organised series of aerial reconnaissance over an experimental smoke screen in an area free from enemy activity. This was done in Northern Ireland between December 1940 and March 1941, with a meteorological officer acting as observer. As a result of

these observations, the early plans were modified. When A.A. Command took control of smoke screen work, the Camouflage Section made further aerial reconnaissances which led to the discontinuation of the use of small orchard heater smoke generators. Later aerial observations were made by C.D.E.S., Porton, and assessments made of the Haslar, Esso and chemical smoke generators. These assessments formed the basis of the latest practice in smoke screen design.

The original schemes, laid down in June 1940, used a small oil burning generator of the orchard heater type which consumed about two gallons of diesel oil per hour. The layout used a circuit of radius 2,000 to 3,000 yards with the generators 10 yards apart. Radial lines of generators at a spacing of five yards were used in light winds. As a result of aerial reconnaissance, the generator spacing was soon reduced to five yards and late in 1940 the radial lines of generators were replaced by an inner circuit of radius about 1,000 yards. The use of this type of generator was finally discontinued in favour of Haslar generators in November and December 1943, as it had become clear that the cover provided by the former type was inadequate. The Haslar generator was a large mechanical generator mounted on a trailer and towed by a lorry. It produced about fifty times as much smoke as the small orchard heater type. A few Haslar generators had been available from the outset, but they did not become available in sufficient numbers to allow incorporation in a definite programme until 1941. In June 1941, the principle of using only Haslar generators on outer circuits and the small orchard type generator on inner circuits was accepted. The early circuits planned with the Haslar generator were based on a spacing of 150 yards and a minimum radius of the outer circuit of 1,500 yards. (A minimum radius was necessary in order to ensure join up of individual smoke trails). In 1942, aerial reconnaissance led to the spacing being reduced to 85 yards. Modifications to the generator in June 1943 led to the spacing being increased again to 120 yards.

In August 1943, after the successful R.A.F. raids on certain dams in Germany, it was proposed to screen several dams in the United Kingdom with chemical smoke. Aerial reconnaissance showed that screening of these dams was effective even in daylight, and eventually fifteen dams were so protected. Chemical smoke generators had been incorporated in one or two factory screens in July 1943 and by September 1943 the incorporation of such generators in screens had become a common feature. This made possible a successful attack on the problem of finding ' quick cover.' It had previously taken twenty or more minutes for the smoke to build up enough to provide adequate cover. Using chemical smoke generators with electrical ignitions, a layout was designed which reduced this period to about five minutes.

In addition to circuit modifications resulting from new or improved generators, the arc of generators to be ignited when a definite wind direction was forecast was reduced from 180° to 150° in September 1941, and from 150° to 120° in April 1942, the aim being to economise in manpower. It also increased the precision needed in forecasting wind direction under conditions when the difficulty of forecasting a definite direction is greatest.

When smoke screens were first used against aerial attack, they were operated on every moonlight night on which suitable meteorological conditions were forecast. After Operational Control was instituted in April 1941, the generators

were only ignited when enemy aircraft were known to be operating over the area concerned. This resulted in a great saving of fuel and manpower but had comparatively little effect on the meteorological effort as the meteorologist still had to be ready with the appropriate meteorological advice at a few minutes' notice. When smoke screening was first proposed it was intended to use the screens only when the lunar illumination exceeded a certain value. This condition was gradually abandoned. In December 1940, screens were operated at Derby and Nottingham on several non-moonlight nights. In September 1942, it was decided to operate the screens at Liverpool, Plymouth, Billingham, Chatham and Portsmouth, which were by that time all using Haslar generators every night, subject to the operational control mentioned above instead of on moonlight nights only.

At the beginning of smoke screening, there was considerable difficulty in devising a suitable layout for coastal sites owing to the guidance given to enemy pilots by land-water boundaries ; it was of little use obscuring the actual targets if the configuration of the coast could lead the pilot to within a short distance of the target. There was the additional difficulty of providing a screen on occasions when the wind was on-shore. This difficulty was partly overcome when the Haslar generators became available in numbers since their greater obscuring power permitted a layout covering a bigger area. The idea of using waterborne Haslar generators was examined and accepted in October 1941, but difficulties in obtaining the equipment prevented the complete implementation of this proposal.

Arrangements for D Day

The allocation of smoke screens was radically changed in April 1941 to meet the needs of the forthcoming landings in Europe. Screens were allocated to 20 ports, most of which had not been screened previously. All these screens used Haslar generators, with some chemical generators, except two ports where the Esso Generator, which was similar to the Haslar, was used instead of Haslars. All except two of the screens were also provided with quick cover circuits and all were arranged to operate independently of the lunar illumination. In the event, it was not necessary to put these safeguards into operation during the critical four weeks or so, except in one or two isolated cases.

Smoke Screens Overseas

One Pioneer Smoke Company was detached in July 1944 for special field training in smoke in view of possible service overseas. A meteorological officer was attached to the company to help in the training. By the end of September 1944, three other Pioneer Smoke Companies had been similarly detached for special field training in smoke, a meteorological officer being attached to each. Three of the companies went overseas in October or early November 1944, taking the meteorological officers with them. The fourth company was turned over to other duties in November 1944.

Work for the Ministry of Supply

Meteorological offices were maintained at a number of Ministry of Supply establishments. At Shoeburyness, the main work was the supply of meteorological information needed in Range and Accuracy and Prize Scale Trials ; this

involved making a very large number of upper wind determinations by means of pilot balloons or observations of shell burst. Periodically, forecasts in connection with the acoustics of firing large guns at Grain Island or in the Thames Estuary were supplied and artillery Meteor reports were regularly provided both for flat fire and anti-aircraft fire. In April 1941 more accurate weighting factors were prepared for anti-aircraft fire. Similar work was done at Eskmeals. At Aberporth, detailed information was supplied regarding wind structure in connection with artillery trials and the development of projectiles (rockets).[1] At Penclawdd, meteorological information was supplied in connection with the development of certain equipment; some experiments were made to determine the effect of a steep cliff on vertical wind velocity and the vertical gradient of wind near a tower was also investigated. At Porton, meteorological information was provided for the special work of the Ministry of Supply establishment there which was related to defence against chemical warfare.[2]

Supply of Warnings, Forecasts, etc., to Government Departments and Essential Services

Besides providing the special services already described, the Meteorological Office helped a number of Departments and Essential Services by providing forecasts, weather warnings and climatological data.[3] The Air Ministry policy on this matter was set out in February 1941, when it was ruled that meteorological information was also available to those essential public and other services which were of national importance and for the operation of which such information was necessary, and for which proper precautions as to secrecy were practicable. The normal method of safeguarding the security of the meteorological information was to issue it in the form of a coded message to a few responsible individuals. The recipients of the messages then issued such instructions as they considered necessary without mentioning the meteorological factors on which their instructions were based. The arrangements made with the various Government Departments, or with the public services under their auspices are described in the following paragraphs.

Ministry of Fuel and Power

Weather forecasts are of considerable importance to electricity and gas supply companies, particularly during spells of severe weather or rapid changes of temperature, as they enable the companies to gauge the probable load on their supplies and to make appropriate arrangements. Thunderstorms may also affect the working of the electricity grid system and warnings of the possibility of thunderstorms were issued to Central Electricity Board headquarters before the war.

After the outbreak of war, nearly all the gas companies accepted the fact that forecasts were no longer available in the Press or on the B.B.C., but the Central Electricity Board continued to receive a copy of the Daily Weather Report in accordance with arrangements made in 1938. As the Daily Weather Report is a printed document, there was inevitably some delay before the Board

[1] A.M. Files S.72860 and S.51654.
[2] A.M. File S.77867.
[3] A.M. Files S.60250 and S.60251.

received the forecast and it was agreed in May 1940 that they should receive the 'B.B. Report,' consisting of a duplicated weather chart of the British Isles and a general forecast.[1] The report was collected daily by messenger, but even this involved some delay, and from December 1942, the daily forecast was telephoned each morning direct to the National Control Centre of the Board in a special confidential code. This arrangement continued until January 1945, when representatives of the Central Electricity Board, the Ministry of Fuel and Power and the Meteorological Office, meeting to consider what help could be given to the Central Electricity Board in dealing with the morning peak of current consumption, agreed to telephone a forecast each evening at 8 p.m. to the National Control Engineer giving the expected temperature, wind direction and force, and weather for the following morning about 8 a.m. in the London area and inland in Great Britain south of the Tay. On the basis of the forecast and a knowledge of the plant available, the National Control Engineer arranged with the Ministry of Fuel and Power for the B.B.C. and Press to issue a Fuel Warning when he considered consumption of electricity likely to reach a dangerously high level. No reference to the weather was made in these Fuel Warnings which might have been due to a variety of causes.[2] In July 1941, the Electricity Commission had suggested the issue of announcements by the B.B.C. as a means of reducing peak loads. The Air Ministry agreed to help as far as possible, but security considerations ruled out anything which would give the enemy direct information regarding current weather, and the matter does not appear to have been pursued further at that time.

During the winter of 1939–40, two gas companies in the London area, the South Metropolitan and the South Suburban, sought the help of the Meteorological Office, and warnings of the onset of cold weather were supplied in an *ad hoc* code in which the names of fruit were used to indicate the expected conditions and appropriate adjectives to give some indication of the duration of the conditions :—

Apples ..	Onset of cold weather indicated; substantial fall of temperature expected within the next day or two.
Lemons ..	Temperature expected to remain below freezing point day and night.
Cherries ..	Frost accompanied by cold wind.
Green ..	Cold spell not expected to last more than a day or two.
Ripe	Prolonged cold spell probable.

The Glasgow Corporation Gas Department asked in February 1942 for similar information and the same system was used to provide them with the warnings they needed. These arrangements continued in force each winter until November 1944, when a more general system of issuing warnings to all the major gas undertakings in the country was introduced. This developed as a result of the Ministry of Fuel and Power asking in August 1944 for a system of warnings similar to that arranged with the Ministry of Transport for the information of county and county borough surveyors. The code used was substantially the same as that which had been used for the London gas companies, but fog warnings were included. The country was divided into approximately 30 numbered regions to indicate the areas to which the warnings referred. These

[1] A.M. File S.60250.
[2] A.M. File S.83662.

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'Gasco' warnings came into effect on 6 November 1944. Over 50 major gas undertakings were included in the original list of recipients of the warnings and a few others were added later, bringing the total up to about 60.

The Gasco warnings were a comparatively late development in the wartime co-operation between the Ministry of Fuel and Power and the Meteorological Office. The Ministry had first sought Meteorological Office aid two years earlier in connection with a proposed Direction to prohibit the use of central heating in certain classes of premises between definite dates, except by permission of the Regional Fuel Controllers. The problem was discussed by representatives of the Ministry of Fuel and Power, the Ministry of Works and the Meteorological Office in August 1942 and, on the basis of information supplied by the Meteorological Office, it was agreed that :

(*a*) The fixing of dates alone would be unsatisfactory as there would be days outside the permitted period when the internal temperature of buildings would fall to a very low value unless the permitted period was so long as to defeat the object of fuel economy.

(*b*) The most practical method for autumn would be to determine two dates, the first early enough to safeguard against substantial periods of cold weather occurring before it and the second late enough to ensure that no substantial periods of warm weather occurred after it. On the latter date, the ban on central heating would be removed completely. In the period between the two dates, the Regional Controllers would be empowered to sanction the use of central heating on receipt of a warning from the Meteorological Office that a cold spell was expected.

(*c*) To allow for the variation of conditions in different districts the country would be divided into three districts with different dates for each, viz. :

Region	*First Date*	*Second Date*
Scotland	19 September	18 October
North England	26 September	25 October
England south of the Humber and Wales	3 October	1 November

(*d*) A cold spell during the intermediate period would be defined by the following three conditions :—

(i) the mean temperature for the day (24 hours) expected to be 45 degrees or less ;

(ii) the maximum temperature during daylight hours not expected to reach 55 degrees or more ;

(iii) the conditions (i) and (ii) expected to persist at least two days, and not expected to be followed immediately after the two days by a period of mild weather with day temperatures of 55 degrees or more.

(*e*) Subject to Air Staff approval, the B.B.C. would be asked to broadcast notifications of the Ministry of Fuel and Power authority for starting up central heating plant during the intermediate period if this should prove necessary.

(*f*) It would be a considerable help if each evening the Meteorological Office would provide an indication of the degree of stoking required, based on the expected weather conditions for the next day. It was suggested that a scale of five degrees of stoking should be used, viz. : 'bank,' 'low,' 'medium,' 'high' and 'maximum,' the term 'bank' corresponding with a temperature in the neighbourhood of 53° F. with light or moderate winds and generally bright conditions during the day, and the term 'maximum' corresponding with a mean temperature of about 25° day and night with a fresh or strong wind. The three intermediate degrees corresponded with intermediate weather conditions. Again, subject to Air Staff approval, it was proposed to use the B.B.C. for promulgating the information.

The Ministry of Fuel and Power submitted the proposals in September 1942 to the Air Ministry who agreed to them, but with the proviso that on occasion the indication of the degree of stoking might be withheld without notice or explanation. This proviso would cover the cases when the broadcast instructions regarding stoking might, in the view of the Meteorological Office, indicate to the enemy developments which he could not otherwise deduce from his own observations. The arrangements for cold spell warnings were put into effect a few days later and arrangements were also made to provide the Ministry with current and past temperature data for a number of representative towns in the United Kingdom.

The associated problem of reimposing the central heating ban in the spring was examined in February 1943 and found to be rather more difficult in view of certain characteristics of spring weather :—

(*a*) In general, warm spells of only a few days duration can be forecast, but it is very unlikely that a warm period of a week or more could be forecast with any degree of certainty.

(*b*) Warm spells occur very often during March and April and usually last for only two or three days.

(*c*) The possible introduction of double Summer Time in April would entail workers starting work in offices at an hour when the outside temperature is little above the minimum night temperature.

(*d*) Temperature variations throughout Great Britain are generally much greater in the spring than in the autumn.

Several ways of meeting these problems were discussed, and the Ministry of Fuel and Power stated on 19 March 1943 that the ban would be introduced on 17 April in England and Wales and on 8 May in Scotland, and lifted again on 31 October for the whole country. Permission to restart central heating plants between these dates would be given on the Meteorological Office issuing a cold spell warning, and withdrawn on notification of the end of a cold spell. The conditions defining the end of a cold spell were a mean temperature of 50° F. or more for 24 hours, a day temperature of 55° F. or more, conditions which were expected to persist for some days. Arrangements on this basis were made to cover the period 10 April to 1 June.

The arrangements were reviewed in August and September 1943 in the light of experience gained during the previous winter and spring. When the ban was imposed in the spring there was a period during which the mean temperature did not fall below 45° F. but there had been many complaints of hardship, even

in the London area where the mean temperature was in the region of 50° F. Suggestions put forward included raising the temperature limits, but they were found to be impracticable or to defeat the object of fuel economy. It was finally agreed, as a compromise, that cold spell warnings would be issued for an area if the temperature in any large town (one with a population of some 100,000) in the area was expected to be 45° F. or less—the limit of 45° F. had previously been taken as applying to the area as a whole, so that when temperatures were just above 45° F. in most places a few places would have temperatures below 45° F. It was also agreed that Buxton should be treated as an exception in view of its altitude (about 1,000 feet) and that if the ban were lifted after 15 October because of a cold spell, it would not be reimposed before the general lifting of the ban on 1 November. It was also arranged for the Meteorological Office to notify the Ministry of Fuel and Power on the first occasion that a spell of some days with a day temperature below 60° F. was expected in any region. This was to guide Regional Controllers in issuing permits to individual premises.

Some relaxation of the conditions was contemplated in March 1944 either by issuing limited permits or by raising the temperature limits, but was abandoned because of a rapid deterioration in the fuel position, and the same criteria and organisation were used in the spring of 1944 as in 1943. One change was made in the definition of the areas as a result of the ban in 1944 applying to any form of fuel for heating instead of central heating only. Previously, the Orkneys and Shetlands had been included with the rest of Scotland, as the ban on central heating hardly affected them, but in view of the new regulations, it was decided to extend the period covered by the permits for those islands to 15 June.

For the winter of 1944, the same arrangements were made as before, but after a rather severe spell of weather late in September, the Ministry of Fuel and Power decided to lift the ban completely from 8 October. In the spring of 1945, it was agreed to wait for the first warm spell after 17 April for England and Wales and 8 May for Scotland before imposing the ban and bringing the earlier procedure into force. In the event, this made no difference in England and Wales as a warm spell was forecast on 17 April, a warm spell being defined by the conditions which had previously been used for the end of a cold spell.

Early in 1944, the Ministry of Fuel and Power had forwarded to the Meteorological Office a request from certain Sheffield industrialists for temperature forecasts, on the grounds that factory owners were required by the Factory Acts to maintain a certain minimum temperature, and in the absence of forecasts they had to keep full heating on at weekends in case the weather turned very cold. The suggestion was agreed and it was arranged in March to supply forecasts of weekend temperatures to the Regional Controller, N.E. Region, for the use of major industrial concerns in his area. The forecasts were at first issued on Saturday mornings but this was changed to Friday afternoons. The forecasts covered the periods from noon on Saturday to noon on Sunday and from noon on Sunday to noon on Monday. These arrangements were extended in the autumn of 1944 to cover the whole country, and forecasts were issued regularly to 11 Regional Controllers of the Ministry of Fuel. The forecasts were passed on by the Controllers to those firms which used a large amount of fuel for space heating, the choice of recipients being left to the Controllers.

Ministry of War Transport

The Ministry of Transport had informed the Air Ministry in 1938 that they could dispense with weather forecast in wartime, but the transport services found themselves in difficulties during the winter of 1939–40, and sought the help of the Meteorological Office. The first request for help came from the Southern Railway who, from November 1939, received warnings of the onset of severe weather in the 'Gasco' code. At the end of January 1940, the Transport Priority Committee of the Ministry of Transport also asked for help. It was arranged for a general inference to be telephoned to the Ministry of Transport each morning about 9.30 a.m. and that B.B.C. reports and district forecasts should be sent to the Ministry of Transport and the Railway Executive Committee. The facilities were extended at the beginning of March to include telephoned warnings of frost, snow, gales and fog (for visibilities of less than 200 yards) for the Railway Executive Committee.[1]

Another severe winter in 1940–41 taxed to the full the resources of the local authorities responsible for maintaining the roads in safe condition for traffic, and the Borough of Stepney, the City of Birmingham and the City of Sheffield asked for warnings of snow and frost. These were supplied in an *ad hoc* 'metal' code, *e.g.* :—

Steel	..	snow expected, becoming icy with traffic.
Copper	..	night frost following thaw or rain, producing patches of ice.
Gold	..	thaw expected, probably only temporary.

A much more elaborate system of snow warnings was introduced the following winter as part of the arrangement for mutual assistance in snow clearance made by the Service Departments, the Ministry of War Transport and local authorities. From 18 December 1941, snow warnings in code were telephoned to the Ministry of Transport Divisional Road Engineers, Road Liaison Officers and County and County Borough Surveyors, a total of some 260 individuals.[2] The warnings, prefixed by the code word 'NEBULAR,' were broadcast on the meteorological teleprinter network and then passed to the authorised recipients from the most conveniently situated meteorological station if the warnings referred to their area. In many cases, the surveyor's office was in the same building as the local civil defence headquarters, and it was arranged in February 1942 for the headquarters of the London Civil Defence Region to distribute the warnings on their telephone network to most of the recipients in the London area. This saved considerable time which would otherwise have been spent in making individual telephone calls from the Meteorological Office in London.

The arrangements were reviewed in September 1942, and as a result of experience during the previous winter, it was decided to include information regarding frost and thaw in the system of warnings for England and Wales only, but not for Scotland, and to elaborate the code accordingly. Three types of Nebular warning were arranged, viz. Nebular One—snow warning, Nebular Two—thaw after snow, and Nebular Three—frost warning. The revised arrangements came into effect on 1 November 1942. At the end of that month, the Secretaries of the Regional Canal Committees were added to the list of recipients. The same organisation was maintained without major change for the winters of 1943–44 and 1944–45. In February 1944, the Royal Ordnance

[1] A.M. File S.60250.
[2] A.M. File S.76867.

Factories were added to the distribution list while, in November 1944, the local Scottish authorities were withdrawn, but the warnings continued to be sent to the Divisional Road Engineer, the Regional Transport Commissioner and Deputy Regional Transport Commissioner.

Ministry of Home Security

The Ministry of Home Security first asked for meteorological information in July 1940 when its Operations Branch asked for a daily summary of weather conditions over the British Isles for the preceding 24 hours with particulars of height and amount of cloud, wind strength and direction, visibility, rainfall, etc. The summaries, which were required in connection with air raids, were prepared for 0700 to 1800 and 1000 to 0700 hours each day and sent by messenger to the Ministry. In October 1940, forecasts of the weather at night over enemy bases on the continent, in addition to the daily summaries, were asked for. Various areas on the continent from Norway to Northern France were denoted by letters and two forecasts for these areas for the following night were issued daily, a preliminary one at 11 a.m. and a final one at 5 p.m. A few weeks later, forecasts for the British Isles were also included.

A number of air-raid siren failures were caused in the winter of 1939–40 by moisture collecting and freezing between the bottom of the rotating vane and the casting of the sound box, and in December 1940, Scotland Yard approached the Meteorological Office regarding a system of frost warnings as an alternative to the installation of elaborate and expensive heating apparatus, it being suggested that when a frost warning was issued the sirens should be ' flicked over ' every 15 minutes so that the vanes rotated without emitting any appreciable sound. In consultation with the Engineering Department of Scotland Yard, a system of warnings of conditions likely to affect the sirens was evolved. The warnings were telephoned to the Engineering Department in a ' flower ' code, *e.g.* :—

Violets .. frost only likely to affect sirens in very exposed conditions.
Tulips .. severe frost, likely to affect all sites.

The system was found to be quite effective and was continued in each winter throughout the war. The code word used for the warnings was NERIS, the word siren reversed.

During the winter of 1940–41, the authorities concerned appear to have believed that the use of poison gas against large towns in this country was at least possible, and a system of warnings of suitable weather conditions for this form of attack was accordingly evolved in conjunction with the Ministry of Home Security and General H.Q., Home Forces. It was decided to issue each day a brief indication of the weather to be expected during the hours of darkness in the various civil defence regions. For this purpose the weather conditions were divided into four categories according to their suitability for the use of non-persistent gas, viz. :—

A.1 .. Optimum (anticyclonic calm).
A.2 .. Very favourable (non-anticyclonic calm or light airs).
B .. Intermediate.
C .. Definitely unsuitable (wind more than 15 m.p.h. at 30 feet).

The warnings were started on 15 January 1941, and were issued to the Ministry of Home Security two hours before blackout at first, but at 1630 hours from October 1941.[1] They were then distributed on the Ministry of Home Security communication network. A brief plain language statement of the expected weather conditions was added at the end of the message. These warnings, known as MALMSEY warnings, were continued until the end of the war in Europe.

It was feared in the early summer of 1941 that the enemy might try to set fire to the standing crops and stackyards in this country by means of incendiary weapons, and the Ministry of Home Security asked the Meteorological Office in July 1941 to help in arranging a system of warnings when conditions were likely to be suitable for such an attack, as apart from the state of ripeness of the crops, weather conditions were the major factor in determining this. The warnings, known by the code word MATCHLESS, were begun on 21 July 1941.[2] The messages were passed to the Ministry of Home Security by teleprinter daily about 5 p.m. and indicated the fire risk on the following day from the weather aspect in each of the Civil Defence Regions (excluding N. Ireland) according to a scale of five degrees, viz., negligible, slight, moderate, serious and very serious. The degree of risk was obtained by calculating an index figure based on past weather conditions (rainfall, wind speed, humidity and evaporation) and the weather conditions forecast for the day to which the index applied. The five degrees of risk corresponded to index values of 0, 1–3, 4–6, 7–10 and more than 10 respectively. The warnings were redistributed by the Ministry of Home Security on their communication system, normally to the Regional Commissioners only, but if the risk was classed as very serious in any region, the warning was passed to air raid wardens and police in the region. The MATCHLESS warnings were issued during the harvest seasons in 1941 and 1942, but in 1943 it was decided that their usefulness was not commensurate with the work involved in their preparation and distribution and they were consequently discontinued.

The danger of forest fires caused by enemy action was an associated problem which was also tackled in 1941. Broadly, the method of estimating the risk of forest fires was the same as that applied to crop fires, but it differed in detail. The Forestry Commission approached the Meteorological Office on the subject in August 1941, and it was arranged for warnings of the same type and using the same scale of risk as the MATCHLESS warnings to be issued daily by 5 p.m. for the districts in which the Forestry Commission were mainly concerned. The warnings, known as NICOTINE warnings, were begun on 15 October 1941 and were issued through the Ministry of Home Security and their Regional Centres to the Forestry Commission's Divisional and District Officers and Foresters in the areas concerned. At first, the warnings were only distributed by the Ministry of Home Security when the risk was stated to be serious or very serious, but it was agreed in January 1942 to distribute the ' moderate ' warnings also. It was arranged in March 1943 to supply warnings of spells of dry weather to the Chairman of the Forestry Commission and his two Assistant Commissioners whenever applicable, and at the same time the fire risk warning system was extended to cover the whole country. It was found, when the arrangements were being reviewed in May 1942, that

[1] A.M. File S.6127. [2] A.M. File S.72852.

communications difficulties were being experienced, mainly because of overlapping of the Civil Defence Regions and the Forestry Commission areas. It was agreed to discontinue the fire risk warnings for June and July, and plans were made to overcome the difficulties as far as possible when the warnings were resumed in August. It was decided in July 1943, to discontinue the daily fire risk warnings completely and to continue the dry spell warnings only.

Ministry of Agriculture and Fisheries

Individual farmers asked for forecasts occasionally after the outbreak of war, but the Ministry of Agriculture and Fisheries felt unable to grant these requests as they feared that the practice would spread rapidly and it would be impossible to conform to the security requirements of the Air Ministry. By 1942, however, an additional six million acres were under cultivation and the safe harvesting of the grain crops was a matter of vital importance, and in July of that year the Ministry of Agriculture and Fisheries suggested to the Air Ministry that a method of issuing meteorological advice during the harvest season might be devised without violating security requirements. They urged that such forecasts would enable better use to be made of the mobile labour and voluntary workers at the disposal of the County and District Officers. It was later agreed that a few code words indicating broadly the expected suitability of conditions on the next day, with an indication of the further outlook, would suffice. An 'animal' code was devised to indicate the scale of suitability, *e.g.* :—

Category	*Code Word*	*Description*
Good	Dog	No rain before sunset next day ; reasonably dry air ; some sunshine.
Fair	Horse	No rain during the daylight hours, or only slight scattered showers, and in that case a good dry wind ; no heavy rain tonight.
Poor	Sheep	A dull, damp day ; a misty or muggy day with little wind ; appreciable rain tonight and not a good dry day tomorrow ; cloudy and light rain tomorrow.

Code words were also used to indicate the further outlook, viz. :—

Category	*Code Word*	*Description*
Settled	Buy	Probably continuing or becoming fair or good for some time.
Uncertain	Fat	Weather cannot be foreseen after tomorrow.
Unsettled	Sell	Probably continuing bad or poor, or becoming bad or poor again.

It was decided to use the Civil Defence system of numbered regions in issuing the forecasts for the various parts of the country and that the forecasts in their coded form should be telephoned to the Ministry of Agriculture and Fisheries about 5 p.m. for further distribution by telephone or telegram to the Chief Executive Officers of the County War Agricultural Executive Committees. It was decided that this should be the limit of the distribution of the forecasts as such, and that the Chief Executive Officers would simply advise their

District Officers and selected farmers, known to be harvesting, of the desirability of harvesting next day or over a longer period. The District Officers and farmers could then tell their neighbours what they proposed to do. The farmers were to be told that the Executive Officers had confidential information on which to base their advice. The security authorities in the Air Ministry approved the arrangements and the forecasts began on 10 August 1942 and continued until 30 September 1942 by which time harvesting operations had been completed. In 1943 and 1944, the forecasts, known as PABULUM messages were recommended on 1 June, to cover the period of the hay harvest, and stopped on 30 September.

In July 1943, it was arranged with the Scottish Office to introduce a system of harvest forecasts for Scotland. The arrangements and organisation were almost identical with those used for the PABULUM messages but, for meteorological reasons, the Civil Defence areas into which the country was divided, were modified slightly. The Hebrides, Orkneys and Shetlands were omitted from the arrangements. The forecasts, known as TROUBLE messages, began on 16 August 1943.

The need to continue to enforce meteorological security was questioned in Parliament and the Press in March 1945, in view of the changed war situation and the handicap imposed on farmers and fruit growers. The Ministry of Agriculture proposed in March that the B.B.C. should broadcast warnings of spring frosts. This frost warning service began on 1 April 1945, the first Meteorological Office forecasts referring to the United Kingdom to be broadcast by the B.B.C. since September 1939. The warnings were telephoned to the B.B.C. by 12.30 p.m. whenever applicable and were broadcast with the 1 p.m. and 6 p.m. News on the Home Service.[1]

Co-operation with other Government Departments

In February 1940, the Chief Engineer of the Great Ouse Catchment Board applied for help through the Ministry of Agriculture and Fisheries, as there was little spare storage capacity in the Washes and he feared that heavy rain, combined with a tidal surge which might block the outlet, would cause serious flooding. It was arranged for the Chief Engineer to be notified whenever conditions favoured a tidal surge (strong N.W. winds in the northern North Sea) and for the warning to indicate the possibility of heavy rain, melting snow or other conditions likely to release a large amount of water.

From February 1942, during work by the Department of Agriculture for Scotland which included diverting the course of the River Nith at Dumfries, forecasts of rain and other factors affecting the work were supplied to the Engineer in charge so that valuable machinery could be moved from the river bed and extra precautions taken to ensure that the river did not break back to its old course.

The Ministry of Food were helped in various ways. Forecasts of temperature and humidity were issued in May 1940 to the Torry Research Station in Aberdeen in connection with fish smoking apparatus. From 28 October 1941, forecasts and outlooks were supplied to the Milk Movements Branch of the Ministry. It was arranged in May 1944 to supply the Milk Division with warnings of

[1] A.M. File S.98431.

spells of hot, very cold or foggy weather, conditions which were likely to affect the supply of milk either 'at source' or in distribution. The Ministry were faced with the problem in December 1943 of moving over 2,000,000 tons of Scotch seed potatoes by sea, a method of transport which they did not normally favour as the potatoes are liable to damage by frost while waiting shipment or discharge. It was arranged to supply frost forecasts for the various ports concerned during the critical period.[1]

The Ministry of Works and Buildings were also interested in frosts and other weather conditions likely to affect their building programme. From time to time, forecasts were supplied as required to their resident engineers on various sites, probably the most important being the series of daily forecasts issued from November 1943 to April 1944 while large grain silos were being erected at six separate sites throughout the country. The silos were erected in a series of operations, each operation lasting about eight days, and as concrete was used, it was important for an operation not to be interrupted by frost if this could be avoided. The forecasts, which gave a general indication of the likelihood of frost in the next few days, were telephoned each afternoon to the Ministry of Works.

[1] A.M. File S.60250.

CHAPTER 17

CIVIL AVIATION

The Department of Civil Aviation was evacuated to Bristol soon after the outbreak of war, and from then until February 1941, a meteorological liaison officer was established at the Department H.Q. The Senior Meteorological Officer at Whitchurch (Bristol) performed the liaison duties from February to September 1941, after which meteorological matters were dealt with directly between the Department of Civil Aviation and the Meteorological Office.

The necessary arrangements for providing meteorological information for a new route were made by the Operational Services Branch of D.G.C.A. and the Meteorological Office and were then promulgated as part of the relevant 'Instruction for Scheduled Service Operation' (I.S.S.O.) for the route in question. All negotiations were conducted through Operational Services Branch and there was little direct correspondence between the Meteorological Office and the operating company.

In general, meteorological services were not provided specially, or even primarily, for civil aviation, but civil aviation needs were always taken into account when the provision of meteorological facilities in any area was discussed, the overwhelming consideration being the need to make the best use of the available meteorological personnel and equipment.

In the areas where meteorological war organisation was in force, the regulations for the operation of civil aircraft had to comply with the meteorological security regulations. The civil pilots felt the effect of these restrictions very keenly as they were accustomed to making full use of a complex international organisation and of a highly developed system of ground to aircraft communication. Within the limits imposed, however, every effort was made to provide them with adequate meteorological information, the general principle being to give as much information as possible to the crews on the ground and to restrict to a minimum the transmission of meteorological information to aircraft in the air. From the security aspect, civil aviation presented a number of problems which did not arise in dealing with Services, as British and Allied civil aircraft operated to and from neutral countries and a number of neutral air lines operated in Allied territory.[1] The arrangements for particular cases are described below. The airlines operating between the United Kingdom and Sweden are dealt with in some detail as they were an extreme example in which meteorological security was in force in both countries and reports were not being exchanged. In these circumstances, with the German Intelligence and Listening Services in the background, arrangements were necessarily somewhat complex.

Services for Internal Air Routes and Routes to Eire[2]

Meteorological offices were maintained during 1939 and the first part of 1940 at the following civil aviation stations: Bristol, Manchester, Liverpool, Belfast,

[1] *See* Appendix 12 for general regulations.

[2] A.M. File S.77455.

Heston, Shoreham, Exeter, Weston, Cardiff and Perth. In 1940, the R.A.F. took over Heston, Exeter, Shoreham, Weston, Cardiff and Perth and only at Bristol (Type 2), Liverpool (Type 2) and Belfast were meteorological offices maintained for the express purposes of briefing civil pilots. The Naval Meteorological Service took over the Belfast office in 1944. Special arrangements were, however, made at Perth in connection with the flights by civil aircraft.

Most of the internal cross-water routes were maintained during the war *e.g.* :

Inverness—Sumburgh.
Aberdeen—Sumburgh.
Liverpool—Ronaldsway
Renfrew—Stornoway.
Renfrew—Islay.
Glasgow—Belfast—Liverpool.
Liverpool—Dublin (West Coast Air Lines and Aer Lingus Teoranta).

At stations such as Aberdeen, Renfrew and Stornoway, meteorological advice was given by the meteorological office at the R.A.F. station on the airfield or in the vicinity. Further details of the meteorological services on the individual routes are given in the following paragraphs.

Allied Airways (Gandar Dower Ltd.)

Route : Dyce (Aberdeen) — Wick — Grimsetter (Kirkwall) — Sumburgh (Shetland), once daily on weekdays.

Several meteorological offices were concerned with this route, and provided the following services :[1]

Meteorological Office	*Information Provided*
Dyce (Type 3)	Route forecast, prepared by the Type 1 office at H.Q. No. 18 Group, for outward and inward flights together with route reports.
Wick (Type 2)	Route forecasts.
Kirkwall (Halston, Naval Met. Office)	Route forecast to Sumburgh and Aberdeen, latest route reports including Sumburgh reports.
Sumburgh (Type 3) ..	Route forecast to Kirkwall or Aberdeen, prepared by the Type 2 office at Sullom Voe, and latest route reports.

After the meteorological office, Dyce, was closed in January 1945, forecasts were sent by teleprinter from H.Q. No. 18 Group to Allied Airways, Dyce. The Civil Control Officers at Dyce were instructed in compilation of A.L.C. reports.[2] It was arranged in February 1945 for a weather report made at 0800 hours by Flying Control, Inverness, to be transmitted to Dyce.

At the request of Allied Airways, it was arranged for the A.L.C. reports, transmitted by Sumburgh to their aircraft, to indicate the gustiness of the wind, in the form of 'ggf' where 'gg' is gust speed in m.p.h., and 'f' the multiple of 5

[1] I.S.S.O. No. 9.

[2] The A.L.C. was a confidential code for transmitting weather reports to aircraft about to land.

to be added to 50 to give the mean speed, using 0 for mean wind below 50. This additional information was needed in view of the light type of aircraft flown and the high winds met on this route.

Great Western and South Air Lines

Route : Lands End—Scilly Isles, twice daily except Sunday.

A forecast for the route for the period 0830–1700 hours was telephoned daily at 0830 hours in Telmet code by the meteorological office, H.Q. No. 19 Group to the Chief Pilot at Lands End airfield.[1]

The service operated until February 1942, without meteorological protection. The existence of the route first came to the notice of the Meteorological Office in that month whereupon protection was arranged.

Isle of Man Air Services

Route : Ronaldsway (Isle of Man)—Speke (Liverpool), three times daily except Sunday.

For the flight from Speke to Ronaldsway, the meteorological office at Speke provided a route forecast, a landing forecast for Ronaldsway, and latest reports from Blackpool and Ronaldsway. For the return flight, information was sent from Speke to Ronaldsway, where there was no meteorological office, as follows :—[2]

(*a*) Before January 1943 (approx.), transmission was in cypher, the route forecast having been coded at Speke in Previ code and the landing forecast in Prog code, over an H.F. radio link between Barton (Manchester) and Ronaldsway and by teleprinter between Barton and Speke.

(*b*) After January 1943, transmission was by telephone in Previ and Prog code from Speke to H.Q. No. 9 Group, Preston, thence by meteorological teleprinter to the meteorological office, R.A.F. Andreas (Isle of Man) whence the forecasts were telephoned to the Control Officer at Ronaldsway. Current weather reports made by the Control Officer, Ronaldsway, were transmitted from Ronaldsway to Speke over whichever of the above channels were in use.

(*c*) Following the closure of H.Q. No. 9 Group in September 1944, communication between Speke and Ronaldsway was via No. 15 Group, but, owing to delays experienced, direct telephone transmission in Telmet code was authorised in March 1945.

Railway Air Services

Route : Liverpool—Belfast—Glasgow, once daily through service each way Liverpool—Glasgow via Belfast, and also once daily each way Liverpool—Belfast.

The meteorological offices at Speke, Belfast Airport and Abbotsinch provided forecasts and route reports for each service. The forecasts issued by Belfast Airport were compiled by the Type 2 office at Aldergrove and later by the Type 1 office at H.Q., R.A.F.N.I. In April 1944, the Air Ministry Meteoro-

[1] I.S.S.O. No. 19.

[2] I.S.S.O. No. 12.

logical Office at Belfast Airport was closed on the transfer of the airfield to the Admiralty and the supply of information to Railway Air Services was taken over by the Naval Meteorological Office established there.[1]

Scottish Airways Ltd.

(*a*) Route : Inverness—Grimsetter (Kirkwall)—Sumburgh (Shetland), twice daily to Kirkwall, once to Sumburgh.

Forecasts and route reports were provided at Inverness by the Type 1 office at H.Q. No. 13 Group Inverness, and at Wick, Grimsetter and Sumburgh, as for Allied Airways. From May 1943, at the Company's request, special reports of sleet or snow showers were added to A.L.C. landing reports transmitted to Scottish Airways aircraft as follows : for continuous snow or sleet, the figure 7 was used for weather in the group PPW, while for showers of snow or sleet, two PPW groups were sent, the first being PP7 and the second PP8.

(*b*) Route : Renfrew—Tiree—Barra—Benbecula—North Uist—Stornoway—once daily in each direction.

Forecasts for the north-bound flight were prepared by the meteorological office, R.A.F. Abbotsinch, and, with route reports, telephoned to Renfrew half an hour before take-off.[2] Until December 1942, a forecast and route reports for the return flight were sent in Telmet code by priority telegram to Stornoway to be available half an hour before take-off, but the meteorological office established in the autumn of 1942 at the new R.A.F. station Stornoway, provided forecasts for the return flight as from December 1942. A.L.C. reports at Sollas (North Uist) were made from 1943 by the civil wireless operator there against a small payment by the Meteorological Office.

(*c*) Route : Renfrew—Campbeltown—Islay, twice daily each way.

Forecasts for the return flight were telephoned to Renfrew from the meteorological office, Abbotsinch, while enquiries were answered by the meteorological office, R.A.F. Port Ellen, Islay, as required.[3]

(*d*) Route : Inverness—Stornoway, three times a week leaving Inverness at 1245 and returning there at 1500. (Commenced May 1944.)

The meteorological office, H.Q. No. 13 Group provided a forecast for the return flight. It was arranged for the coastguard station at Point of Stoer to send a weather report to No. 13 Group at 1200 hours on operating days.

West Coast Air Services Ltd.

Route : Manchester (Barton)—Dublin (Collinstown) till November 1942, then Liverpool (Speke)—Dublin (Collinstown), one service daily leaving England at 1100 and returning at 1520.

Route forecasts for return flight, landing forecasts and weather reports, including one from Collinstown, were compiled at Speke meteorological office. Until February 1942, Collinstown reports were sent to Speke by telegram at 0600, 0900, 1100 and 1300 G.M.T. After that month, with the establishment of teleprinter connection between Dunstable and Collinstown, hourly reports were received at Speke from Collinstown through Dunstable.[4]

[1] I.S.S.O. No. 20. [2] I.S.S.O. No. 17. [3] I.S.S.O. No. 18.
[4] A.M. File S.59818.

Collinstown transmitted, on request, a very brief landing report in clear to West Coast Air Services aircraft, *e.g.*, cloud height 500 ft., but there was no arrangement for supplying them with regular landing reports in A.L.C. or other code at Collinstown.

Aer Lingus Teoranta (Eire Service)

(*a*) Route : Dublin (Collinstown)—Manchester (Barton), later Liverpool (Speke), a return flight from Collinstown leaving there about 10 a.m. and returning about 1500 with three hours stay at Barton or Speke.

Incoming : Collinstown to Barton or Speke.

Before February 1942, a fixed time telephone call was made from Collinstown to Barton half an hour before take-off and Barton then telephoned a coded report for Barton, a forecast in Previ code for the route and a coded landing forecast for Speke, Valley and Woodvale in Prog code. After February 1942, the information was transmitted by teleprinter through Dunstable. The service was suspended between April and September 1944, for security reasons.

Outgoing : Barton to Speke or Collinstown.

Route and landing forecasts with weather reports were provided by Meteorological Office, Speke. Authority was given in November 1942, on the transfer of the terminal to Speke, for the Irish pilot to see the weather maps at Speke.[1]

Up to February 1945, Collinstown transmitted a cyphered landing report to Aer Lingus Teoranta aircraft in flight from Speke, but in that month, following a request from the company alleging delay in receipt of Collinstown reports at Speke by teleprinter, it was arranged with Eire Meteorological Service for this report to be transmitted to Speke before take-off.

(*b*) Route : Croydon—Liverpool.

In November 1944, services between Croydon and Liverpool were instituted by Associated Airways Joint Committee and Aer Lingus Teoranta in connection with the Dublin—Liverpool services.[2] Forecasts, route reports and A.L.C. landing reports were provided by the meteorological offices at Croydon and Speke.

Associated Airways Joint Committee

Route : Renfrew—Prestwick—Croydon.

This service began in February 1945. Route and landing reports in A.L.C. were supplied by the meteorological office at Abbotsinch (for Renfrew), Prestwick and Croydon.

Services for European Civil Aviation

Shortly after the outbreak of war, most of the European air services were terminated, the London—Paris service being an exception. Neutral air services operated for a time to Shoreham and the Norwegians for a time to Perth.

[1] I.S.S.O. No. 4. [2] I.S.S.O. No. 25.

United Kingdom—Sweden

Flights were made between Scotland and Sweden by both B.O.A.C. and A.B.A. (Swedish) aircraft. They were important in bringing Swedish goods of great value for war production. Mosquito aircraft, which came into use in 1943, twice made the crossing by day, otherwise all flights were made at night. Cloud cover over the Skaggerak area was essential for safety from German fighters. Up to 1944 the route was direct to Stockholm across the Skaggerak but after that a route crossing Norway at latitude 62½° N was used. Most flights went direct to Stockholm, but Gothenburg was also used.

The scarcity of meteorological information from much of the route, and the exacting nature of the requirements for safety from the enemy and weather perils made forecasting difficult. Great care had to be taken to arrange signalling between terminal airfields and between ground stations and aircraft so that the enemy could draw the minimum inference about weather conditions over Scotland.

B.O.A.C. Flights: Flights by B.O.A.C. aircraft to Stockholm began in April 1940, at first from Perth, but from Leuchars after February 1941. The flights were infrequent at first, but became more frequent until towards the end of the war,[1] 5 or 6 aircraft sometimes crossing on suitable nights. The general security regulations were :—

(*a*) Pilots and representatives of British and Allied aircraft were permitted to see weather maps ;
(*b*) no written statement about weather was given to aircraft crew ;
(*c*) no meteorological reports were transmitted from the aircraft ;
(*d*) the crew were warned not to divulge any weather information to unauthorised persons ;
(*e*) Landing Reports for United Kingdom bases were transmitted to aircraft on request in A.L.C. cypher.

The initial arrangements made in 1940 for the supply of forecasts, which were adequate at the time, but which proved unsatisfactory, when flights became more frequent, were as follows :—

(*a*) *Outward Flights from Scotland*: A forecast for the eastern half of the route (11° E. to Stockholm), prepared by the Swedish Meteorological Office, was cabled by the Air Attaché, British Legation, Stockholm, to the British terminal. The meteorological office at H.Q. No. 18 Group or at Leuchars, provided a route forecast and reports for the whole route. On the basis of these forecasts and of military advice, the Control Officer decided whether the flight should take place, and cabled the expected time of arrival to the Air Attaché. A forecaster attended at the airfield to brief crews before take-off, if none was permanently located there, as was the case at Perth and Leuchars in 1940 and part of 1941. If reports received after take-off indicated serious deterioration the Control Officer transmitted a navigational instruction for recall or diversion to the aircraft without mentioning weather.

All cables to and from Stockholm were in cypher and passed through Civil Aviation Directorate, Air Ministry, Bristol.

[1] I.S.F. No. 1. A.M. Files S.80857 and C.S. 12022.

(*b*) *Incoming Flights :* A forecast was provided by H.Q. No. 18 Group or Leuchars at 1445 hours on the afternoon of the flight. On that and military advice the Control Officer cabled ' suitable ' or ' unsuitable ' to the Air Attaché. No meteorological information was allowed to be included in this cable.

The Swedish Meteorological Office provided a route forecast for Sweden only before take-off.

On the transfer of the terminal to Leuchars in 1941 B.O.A.C. withdrew their operational officer and handed responsibility to the R.A.F. Flying Control. R.A.F. Flying Control included portions of the forecast in the ' suitable ' or ' unsuitable ' message to Air Ministry, Bristol, who passed it on to the Air Attaché. This practice grew up without Meteorological Office or Intelligence authority.

In 1942 it became clear that provision was necessary for warning the Air Attaché just before take-off that the flight should not take place, and for sending other urgent information which could not be done with the delay involved in cabling. In August 1942, therefore, it was arranged for the Air Attaché to receive in the Embassy cyphered wireless messages from Leuchars. The meteorological arrangements for incoming flights were then modified, and a route forecast in Previ and a landing forecast in Prog code were broadcast in cypher by Leuchars for reception in the Embassy, provided a ' suitable ' had previously been sent by cable. To prevent the enemy drawing conclusions from the length of these messages a dummy forecast was transmitted if ' unsuitable ' had been cabled, since otherwise he would have realised from the departure of aircraft from Stockholm, which could not be concealed from him, that a long message indicated suitable conditions. A special icing group giving icing index and freezing level was included in the Previ forecast. These forecasts were only to be communicated to B.O.A.C. pilots definitely leaving, and not to pilots remaining at Stockholm for any reason.

Increasing activity during 1942 made it necessary in December to post a Meteorological Officer to the British Legation, Stockholm, to brief B.O.A.C. crews. Facilities were provided for receiving British weather broadcasts and drawing weather charts. To conceal his real functions he was given the cover designation of ' Scientific Adviser to the Air Attaché.' This officer, besides briefing crews on the basis of the forecasts received from Leuchars and his own charts, added his comments to the forecasts prepared by the Swedish Meteorological Office without altering the original text, when those forecasts passed through the Air Attaché's office. He also gave all practicable assistance to ensure the reliability and prompt transmission of the MURIA weather reports compiled at British consulates in Sweden for transmission to London. A second forecaster was posted in September 1943.

From January 1943, to ensure protection against flying into the sea in low flying, a forecast of M.S.L. pressure, visibility and state of sea at 58° 10′ N., 09° 30′ E. was added to the Previ forecast for westward flights.

Early in 1943 there was considerable pressure from B.O.A.C. and D.G.C.A. for the transmitting of certain three-letter uncyphered code signals from Stockholm to Leuchars to provide for last-minute cancellations. These were to

be additional to the plain departure signals transmitted by the aircraft after take-off. All signals from which weather inferences could be drawn were to be cyphered and plain language signals were accordingly restricted.

From February 1943, to reduce delay, the Swedish Meteorological Office forecasts, with the British meteorological officer's comments, were encoded into Confidential Meteorological Code in the Legation and then cyphered for cabling. They were preceded by the code word PASTIME to ensure immediate despatch to Leuchars from the Air Ministry Communications office.

From May 1943 weather observations were made by B.O.A.C. crews at five points on the route and these were written on a special form handed on arrival to the meteorological officer at Leuchars or the Stockholm Legation.

Liberator and Dakota aircraft were put on to the service in October 1943 using the northern route. As some of these used Gothenburg airport arrangements had to be made for the Meteorological Officer at Stockholm to telephone cyphered forecasts to the British Consul at Gothenburg for handing to the crews. On two occasions one of the forecasters travelled from Stockholm and prepared a briefing in the British Consulate at Gothenburg using information telephoned from Stockholm.

In February 1945, it was arranged with the Swedish authorities for the forecasts, previously sent to U.K. by cable, to be transmitted by wireless in cypher from Stockholm airport to Leuchars.

The B.O.A.C. service was extended to Helsinki (Finland) once a week from March 1945. Forecasts for the Stockholm—Helsinki route were provided by the Swedish Meteorological Office.

With the end of the War in Europe on 8 May all flights were made by day and it was arranged for the British meteorologists at Stockholm to work in the Swedish Meteorological Office at the airport and to prepare forecasts jointly with the Swedish staff. All signals were thenceforward sent in plain language.

Finally, in June 1945, the British terminal was changed from Leuchars to Croydon and the Meteorological Office H.Q. No. 46 Group and Croydon took over from H.Q. No. 18 Group and Leuchars the meteorological protection of the route.

U.S.A.A.F. Flights: Flights by U.S.A.A.F. aircraft to Stockholm began from Leuchars in May 1944, transferring to Metfield (Norfolk) in November. They were provided with the same information as that available to B.O.A.C. aircraft.

Flights by Swedish Aircraft: Aircraft of the Swedish Company Aktiebolaget Aerotransport operated a service between Dyce and Stockholm from April 1942. It was never operated during the summer months, when there was a full moon, and was suspended for periods owing to German interference, and from April to September 1944, on British order, during the preparation and initial stages of the landings in Europe. The route crossed Norway between 62½° and 65° N.[1]

Security difficulties were naturally greater than for B.O.A.C. aircraft. Swedish pilots were not allowed to see weather maps in Britain and were not briefed by the meteorological officer at the British Legation, Stockholm, of

[1] A.M. File S.77469. I.S.S.O. No. 21.

whose existence they were supposed to be ignorant. The forecasts given to them at Dyce by the meteorological office were, as far as possible, confined to an indication that weather was or was not safe. Landing reports in A.L.C. cypher were transmitted to them on request, special key groups being used for the Swedish service.

The general organisation, as originally planned, was as follows:—

(*a*) *Flights from Dyce to Stockholm:* A forecast for the eastern part of the route, prepared by the Swedish Meteorological Office, was cabled to Dyce through the Air Attaché, Stockholm, and Air Ministry, and handed to the pilot in writing. In addition, a restricted forecast prepared by H.Q. No. 18 Group was read to them.

(*b*) *Flights from Stockholm to Dyce:* 8½ hours before the estimated time of departure from Stockholm, a route forecast was supplied to the Control Officer, Dyce, who decided, in conjunction with Air Ministry, whether to cable 'suitable' or 'unsuitable' to Stockholm. No meteorological information was included in this signal.

Conditions regarded as suitable were initially:—

Weather at Dyce—visibility over 2 miles, cloud base over 2,000 feet.
On the route—head wind less than 40 m.p.h., no dangerous weather, and no icing risk below 2,000 feet.

The exact conditions were later changed, the limits for visibility and cloud height being reduced to 1 mile and 600 feet and the headwind increased to 60 m.p.h. from August 1942. If weather made diversion or recall necessary, the arrangements were the same as those made for B.O.A.C.

The A.L.C. cypher reports transmitted by Dyce consisted of the Dyce report followed by one for Kinloss as that was the first diversion airfield.

It had been proposed that there should be transmissions by wireless in 'Q' code (uncyphered) between Dyce and Stockholm airport, stating aircraft leaving or not leaving and giving weather information, but D.M.O. and D. of I. ruled that any weather information sent to the Air Attaché, and all signals from which inferences as to weather could be drawn, must be encyphered. With the introduction in August 1942 of wireless reception in the British Embassy at Stockholm, 'delay' and 'go' messages for this service were sent in cypher through that channel two hours before take-off, with a forecast of the mean upper wind at 10,000 feet over the western part of the route. Dummy forecast groups were sent with a delay message. An upper wind forecast was also added from that time to the cable sent eight hours before departure.

From January 1943, the Swedish Meteorological Office forecasts for A.B.A. were cyphered in the Embassy with those for B.O.A.C. and sent with comments of the British Meteorological Officer, Stockholm, to H.Q. No. 18 Group and Dyce. These comments were not allowed to be shown to the Swedish pilot at Dyce.

Late in 1942, A.B.A. asked for forecasts of the general height of freezing level and wind at 1,000 feet over the western half of the route to be transmitted to Stockholm before west-bound flights. This information was added, from February 1943, to that already supplied, on the understanding that the weather information would only be handed to Swedish crews immediately before departure.

A Swedish aircraft was shot down by a German fighter in October 1943 and the service was suspended until February 1944 when it was resumed under a German safe-conduct which involved informing the German Embassy that the aircraft was leaving. The Meteorological Office objected to this procedure, but the service operated under it for only a short time before it was suspended in April 1944 by British order. The service resumed in September 1944 without German safe-conduct and the terminal was changed to Prestwick. From May 1945, full facilities were given and M.O.O.F. procedure was brought into force. The terminal was changed again from Prestwick to Croydon in June 1945.

United Kingdom—Russia

Meteorological arrangements were made in 1942, in co-operation with the Hydro-Meteorological Service of Russia, for a United Kingdom—Moscow service.[1] The general organisation was developed on lines similar to that in operation for transatlantic flights, with a special forecast section at Prestwick. Briefing for west-bound flights was carried out at the Central Weather Institute in Moscow by Russian meteorologists through the medium of an interpreter.

Because of the difficulty of operating the direct route to Moscow during the winter, a 'Southabout' route was developed later from Lyneham via Cairo, Habbaniya, Teheran, Kubishev. A great part of this route coincided with the main civil route as far as Habbaniya.

United Kingdom—Lisbon

In 1940, K.L.M. began to operate a service from the United Kingdom to Lisbon. This route constituted one of the most valuable links between Britain and the outside world throughout the war, as it was the first section of a number of overseas routes.

Services for Empire and World Civil Air Routes (Excluding N. Atlantic)[2]

For some time after the outbreak of war, little change was needed in the operation of large sections of the Empire air routes. Close liaison was maintained with the various Colonial, Dominion and other authorities responsible for providing information to civil aircraft, and assistance was given to the selection and training of meteorological staff in various areas, *e.g.* Sudan, West Africa, East Africa, Iraq. Security considerations necessitated changes on the section of the Flying Boat route from the United Kingdom to the Mediterranean via St. Nazaire and Biscarosse. The main Empire Air Base was transferred from Hythe to Poole where it remained for the duration of the war. During the first half of 1940, all route forecasts for the Channel sector of the route from United Kingdom to Biscarosse and landing forecasts for Poole were sent in code via Paris to Biscarosse and St. Nazaire.

As a result of Italy entering the war, the air route through the Mediterranean to the East was severed. The only route to the Middle East and India was then via Lisbon, or Gibraltar, to West Africa where it connected with various

[1] A.M. File S.73793.

[2] A.M. File S.69114.

routes from Nigeria to the Sudan or East Africa and thence to Cairo by way of the Nile, or to India by way of Aden and the South Arabian coast. On account of the large number of interconnecting routes, and the temporary nature of many of them, their meteorological services will be dealt with according to stations and areas rather than according to routes. The meteorological organisation served the military requirements for ferry, transport and reinforcement aircraft and the requirements of Civil Aviation.

Home Bases

The main civil routes to the south were served at first by Poole for flying boats and Bristol (Whitchurch) for landplanes. The most important landplane service for some time was that operated by K.L.M. from Bristol to Lisbon. The main flying boat services were from Poole to Lisbon and from Lisbon to West Africa.

An important development in September 1940 was the establishment at Gloucester of a meteorological centre for the purpose of providing meteorological forecasts and information for all civil and service flights out from and into the United Kingdom. In so far as the Atlantic was concerned, the meteorological office at Prestwick came to play a far more important role than that at Gloucester.

The loss of reports from France and the French African colonies, together with the need to safeguard the secrecy of any available information, at first proved a serious handicap, but a reasonably satisfactory organisation was developed by the end of 1940.

The introduction of an intermediate stop at Shannon in May 1941 on the Poole–Lisbon service meant that the responsibility for forecasting on the flying boat route was shared between Gloucester and Shannon, the former being responsible for the section of the route Poole–Shannon and the latter for the section of the route Shannon–Lisbon.

Later, when the land bases were established in North Africa, the stations at Lyneham and St. Mawgan became Civil Aviation bases and, later still, when it was possible to fly across France, the main centre of activity was transferred to Hurn. In all cases, Gloucester was responsible for issuing the basic forecasts and analyses for the route, the briefing and meteorological documentation for the flight being done by the meteorological office at the departure airfield.

For the information of meteorological stations at Gibraltar and in North Africa, routine route and landing forecasts were issued four times daily from Gloucester for interception at these stations. The route forecasts were in respect of the section of the route north of Lat. 43° N.

Lisbon

In August 1941, a meteorological officer was attached to B.O.A.C. and posted to Lisbon to improve the meteorological facilities available to the Corporation's aircraft.[1] It was possible at the Lisbon office to intercept the routine transmissions of route and landing forecasts issued by Gloucester and Gibraltar but, to ensure reception of the issues which were essential for the movement of

[1] A.M. File S.79941.

civil aircraft, special transmissions were made on Civil transmitters from Bristol (Whitchurch). It was not permissible for the Lisbon office to transmit information but in 1944 the meteorological issues from Cintra were greatly extended and it was usually possible to intercept hourly reports before and during flights from the United Kingdom to Portugal.

Gibraltar

As soon as the military situation in Libya permitted, the journey to the Middle East was shortened by starting a service through the Mediterranean. This was done from 12 October 1941, by means of flying boats, the route being United Kingdom—Lisbon—Gibraltar—Malta—Cairo. The meteorological office at Gibraltar co-operated with Malta for the Gibraltar–Malta section of the route but it was difficult to arrange the satisfactory supply of meteorological information on the Lisbon—Gibraltar section of the route as cable communication between Gibraltar and Lisbon was too slow to ensure the receipt at Lisbon of an up-to-date landing forecast for Gibraltar, and the 'suitable' or 'unsuitable' code procedure, which was the most that could be sent from or received in neutral territory, was meant to cover all operational requirements besides weather and was, therefore, not satisfactory in practice. Owing to the difficult landing conditions at Gibraltar, an aircraft had to have the most accurate forecasts possible, which could only be ensured by sending the forecasts of landing conditions to the aircraft immediately it was airborne. The Captain could then return to Lisbon if adverse conditions were reported.

Later, on the construction of a land airfield at North Front, Gibraltar became an important staging post on routes to North Africa and the Mediterranean. The meteorological staff was greatly increased, there being offices at the land airfield at North Front and the flying-boat base at New Camp as well as an office at Combined H.Q. Routine route forecasts for the section of the route to Gibraltar and French Morocco, south of Lat. 43° N., and landing forecasts for Gibraltar and Rabat Sale were issued four times daily. Forecasts were regularly exchanged with Malta and Cairo for the appropriate sections of the routes Gibraltar–Malta and Gibraltar–Cairo.

West Africa[1]

On the closing of the Mediterranean to civil aviation, West Africa became the main route by which aircraft could be flown to the Middle East and later to India and to the Far East. The maintenance of civil air routes between United Kingdom and West Africa, and between West Africa and Middle East was an urgent necessity for the carriage of priority mails, despatches, passengers, urgent freight and in many cases as a 'return ferry service' for the return of pilots who had delivered aircraft to the operational areas. It was therefore urgently necessary to enlarge the meteorological organisation in West Africa, and the service was taken over by the Meteorological Office. The main forecast offices were established at Bathurst, Freetown, Takoradi, Accra, Lagos, Kano and Maiduguri.

To assist in the task of transporting aircraft, equipment and lease-lend material across Africa, contracts were made with Pan-American Airways Inc. to run services from Bathurst to Khartoum, and from South America to West

[1] A.M. Files S.79656 and S.62220.

Africa. Later the United States authorities included West Africa in the 19th Weather Region of the U.S.A.A.F., and the meteorological offices at the stations mentioned above became in many cases 'joint weather centres' manned jointly by meteorological personnel of the Air Ministry and the U.S.A.A.F. and/or P.A.A.

In addition to stations in British West Africa the two main transatlantic termini for the American service were Robertsfield and Fisherman's Lake, both in Liberia. The forecast offices there were maintained by the American authorities; the Air Ministry provided certain observational facilities.

Bathurst was the point of departure of the B.O.A.C. service to North America via Belem, Trinidad and Bermuda. Meteorological responsibility for this route was shared by Bathurst for a time with New York and later with Trinidad.

Reports from the islands of Ascension and St. Helena became of great importance in connection with the operation of the South Atlantic crossing between South America and West Africa. In 1940 cabled reports from Ascension and St. Helena were sent to Freetown twice daily. Later, however, the U.S.A.A.F. established a main meteorological office at Ascension and hourly reports were transmitted to Accra. The U.S.A.A.F. also assisted in the maintenance of a 24-hour meteorological service in the island of St. Helena.

French Equatorial Africa and Belgian Congo

In order that the route to the Middle East via Kano and Maiduguri (the northern route) should operate successfully, close co-operation had to be maintained with the French Meteorological Service in the Chad area with headquarters at Fort Lamy. Reports from Lamy, Ati and Abeche were of the utmost importance in giving prior warning of harmattan conditions.

When it was found that the one route eastwards from Nigeria was inadequate, a flying boat service was started in 1941 between Lagos and Cairo by way of Libreville, Pointe Noire, Leopoldville, Stanleyville and Port Bell. An additional landplane service was also operated by the Belgian Company SABENA from Takoradi to Juba via Lagos, Douala, Libenge, Stanleyville.

The operation of these routes through French and Belgian territory necessitated close co-operation with the authorities there. Help was given to the Free French at Brazzaville in the form of equipment, and at one stage in personnel, in order that their net-work of reporting stations and programme of meteorological broadcasts might be improved. In 1942, a Wing Commander of the Belgian Meteorological Section, R.A.F. visited the Congo and the foundations of a much more extensive service were laid, involving the opening of a forecast centre at Stanleyville and a considerable number of surface and upper air reporting stations.

Sudan

The operation of the civil routes from West Africa to Middle East involved the co-operation of the meteorological service of the Sudan. It was arranged for the Sudan Government to be responsible for the basic network of observations whilst the Air Ministry would be responsible for providing additional forecast staff and observational stations required for purely operational purposes. Thus meteorological forecast centres were maintained at Khartoum, El Fasher and El Geneina for the 'Northern Route' from West Africa, and an

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observation station at El Obeid. Forecast offices were also maintained at Juba and Malakal in the Southern Sudan and an observation station at Wadi Halfa on the route to Cairo. Later, when the direct route to India was along the South Arabian Coast from Aden, additional observation stations were maintained for some time at Carthage and Summit on the high ground between Khartoum and the Red Sea.

Eritrea

Asmara became an important base on the air route between Cairo and Aden and Cairo and Addis Ababa. A meteorological organisation was developed in Eritrea, with a forecast centre at Asmara and observation stations at Assab, Massawa, Agordat, Nacfa, Keven, Ghinda, Adi Ugri and Adi Caieh.

Aden and South Arabian Coast

The most direct route to India from the Sudan was via Aden and the South Arabian Coast to connect with the trunk route Cairo to India at Jiwani. To ensure the safe operation of this route it was necessary to develop considerably the meteorological organisation in the Aden area. Forecast offices were maintained at Steamer Point and Sheikh Othman at Aden, and observation stations at Riyan, Salala, Masira and Ras el Hadd on the Arabian Coast, at Kamaran and Perim in the Red Sea, at Socotra in the Indian Ocean and at Berbera, Hargeisa and Bender Kassim on the southern shores of the gulf of Aden. Some of the stations on the South Arabian route were operated originally by the India Meteorological Department, but later, owing to difficult living conditions for civilian staff, the operation of the stations passed to either R.A.F. or U.S.A.A.F. control.

Middle East

This area was of the greatest importance in connection with the operation of main trunk routes. In addition, civil air services of more restricted scope operated to meet service requirements, *e.g.* Cairo—Adana, Cairo—Teheran, Cairo—Asmara, Cairo—Libya. The meteorological services of the Air Ministry and of the Egyptian Civil Aviation Department were amalgamated, the combined service coming under the control of the Chief Meteorological Officer of the British Service. The central forecasting office was transferred from Heliopolis to Almaza in May 1940. The R.A.F. also maintained a number of other forecasting offices, the chief of which from the civil aviation point of view were at Almaza and Cairo West. The main American meteorological office, corresponding to the office at Almaza, was at Payne Field, a few miles east of Almaza.

Palestine

About the end of 1940 the Palestine Meteorological Service came under the Meteorological Office, Air Ministry. The principal aerodrome associated with civil aviation was at Lydda, where, initially, a meteorological office was maintained for briefing purposes. Later a full Type 1 meteorological office was established there. Another base used by flying boats was at Kallia on the Dead Sea. Forecasts for this base were supplied from Air Headquarters, Jerusalem. The Palestine Government remained responsible for the basic network of stations; any meteorological station required solely for operational purposes was provided by the Air Ministry.

Cyprus

This was an important staging post on some of the local civil air services maintained in the Middle East, particularly the Cairo—Adana service, Cairo—Beirut—Nicosia, etc. A forecast centre was established at Nicosia and arrangements made to maintain a small, well distributed network of reporting stations manned throughout the 24 hours.

Iraq

The meteorological service, which before the war had been maintained by the Iraq Government, was taken over by the Air Ministry. The principal forecasting centres for the supply of information to civil aircraft were Habbaniya and Shaibah with subsidiary offices at Baghdad and Basra.

Persia

One of the local air services maintained in the Middle East was that from Cairo to Teheran. To provide meteorological service for this route a forecast centre was established at Mehrabad (Teheran) and a network of reports was maintained in Persia partly by the Air Ministry, partly by the U.S.A.A.F. and partly by the Russian authorities.

The meteorological offices at Habbaniya and Teheran were important in connection with the operation of the 'Southabout' services between United Kingdom and U.S.S.R. in 1943. A special organisation was agreed involving the broadcasting of reports from Habbaniya and Moscow and also the exchange of route and landing forecasts.

To supplement the information supplied by the India Meteorological Department at Sharjah and Bahrein, meteorological offices were opened under the Chief Meteorological Officer, H.Q. M.E. These stations made observations throughout the 24 hours either hourly or half hourly and the observations were broadcast for aircraft and ground stations. In 1945 these offices became subsidiary forecasting centres in order to deal adequately with the large flow of transport aircraft.

India

An extensive meteorological organisation was developed in India from 1943 onwards, and although the responsibility for supplying information to civil aircraft rested with the Government of India, nevertheless the basic organisation for the reception and transmission of data was greatly improved and speeded up to the benefit of civil aviation stations as well as to R.A.F. operational and transport stations.

Malaya : Ceylon : Australia

The air route with Australia via Singapore was cut in 1942, and early in 1943 plans were completed for restoring this link by means of long-range aircraft between Ceylon and Western Australia. In October 1943 the route was extended from Ceylon to Karachi, and a through service was then provided from Karachi to Perth (Western Australia) and a direct connection with the main Empire Route.

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Meteorological information at Karachi and Ceylon was provided by the Air Ministry meteorological offices. In order to co-ordinate arrangements and bring the meteorological organisation into line with that in use on other long distance routes, a meteorological officer from Ceylon visited Australia in 1943.

Later in 1945, this service was operated by long-range, land-based aircraft, and a staging post with meteorological station was established at Cocos Island.

When the regular route to Australia via Singapore was re-opened, meteorological information was supplied first by the Air Ministry which maintained forecast and observation stations in Burma, Malaya, Sumatra, and Batavia. The route to Hong Kong was served by the Air Ministry Meteorological Offices at Saigon and Bangkok. The Meteorological Office also assisted in the training of forecasters and assistants for the Netherlands Meteorological Service with a view to the latter taking over meteorological responsibility in the Netherlands East Indies. This took place in the course of 1946.

East Africa and Indian Ocean

The main Flying Boat route from Durban to Calcutta continued to operate throughout the war, meteorological information being provided by the British East African Meteorological Service. This service came under the control of the Meteorological Office Air Ministry in 1943. The basic network of stations was maintained or improved, and the number of forecast centres was materially increased. Most notable changes were made in the Indian Ocean area, where reporting stations were established with a view to improving the standard of forecasting in tropical oceanic and land areas. The number of subsidiary forecast centres was also increased in this area to deal with the civil air services between East Africa and Madagascar.

The Trans-Indian Ocean route, though surveyed in 1939, was not used by civil aircraft during the war period although plans were made for a meteorological organisation to deal with flights along the route Mombasa—Western Australia, *e.g.* a surface and upper air reporting station was established at Diego Garcia (Chagos group).

French West Africa, French Morroco, French North Africa

After the landings in North Africa, it became possible to use bases in French territory for civil air operations. The base in French Morocco was originally Ras el Ma, near Fez, but it was moved later to Rabat Sale. Regular services from this base were operated to Gibraltar, Lisbon, United Kingdom, Algiers, Cairo and West Africa and the Azores. A 24-hour meteorological service was operated by Air Ministry staff and routine exchanges of data, forecasts were established with the majority of these stations.

Another important station on the West African route was Port Etienne. Here the Meteorological Office maintained a liaison officer with the French service. The same arrangement was followed at Dakar, the headquarters of the French meteorological service in French West Africa.

Mediterranean

Despite the closing of the route through the Mediterranean on the entry of Italy into the war, certain special flights were made by flying boats through the Mediterranean at the end of 1941. The meteorological officers at Gibraltar and Malta provided the necessary data for these flights though under considerable difficulty.

After it became possible to use the base at Rabat Sale, it was possible to use the desert route to Cairo. The meteorological organisation for these flights involved forecast exchanges between Rabat Sale (Western Section), Malta (Central Section) and Cairo (Eastern Section).

On the complete clearance of the North African coast, it became possible to use the flying boat route, but the base between Gibraltar and Cairo was transferred to Djerba Island where a forecast unit was established by the Meteorological Office. This unit was transferred later to Augusta.

The principal stations on the land plane routes to Cairo were Algiers (Maison Blanche), Castel Benito, El Adem and Luqa (Malta). Later when it became practicable to use more direct routes across France, it became possible to use certain bases in France and Sardinia, notably Istres, Elmas and Marignane (flying boats and land planes). At all these stations the Meteorological Office maintained forecast centres, the main centre in the Mediterranean basin being at the Area Control Centre at Malta.

West Indies

Meteorological offices were opened at Barbados, Jamaica and Trinidad, in 1940, and were available for civil aviation developments in that area, though they were primarily established for the requirements of the Defence Services. Later, forecasting centres were established at Nassau, Jamaica and Trinidad. The office at Trinidad provided meteorological information for the South Atlantic flying boat service via West Africa, Brazil, Trinidad, Bermuda and Baltimore.

Services for North Atlantic Civil Air Routes

The experimental flights which took place in August and September 1939 and again in 1940 were operated between Foynes and Newfoundland. Although the Government of Eire had assumed responsibility for the base at Foynes, the actual meteorological work for the flights was done by staff of the Meteorological Office, lent for investigational and forecast work. Owing to the security restrictions, amendments to the safety organisation for transatlantic flights (T.A.S.S.O.) were necessary. They were framed at a meeting held in Dublin in April 1940.

The main B.O.A.C. flying boat route, operated regularly after May 1941, was from Newfoundland to Shannon in summer, and Baltimore—Bermuda—(Lisbon)—Shannon in winter. The return leg of this route was as already described via West Africa and Trinidad. The only station on this route not previously mentioned is Bermuda where the Air Ministry took over the meteorological service. For civil flights, Bermuda provided the forecast for the first half of the route to United Kingdom, the forecast for the second half being provided by the Meteorological Office at Gloucester, created in October 1940.

The large increase in transatlantic flying envisaged during 1942 necessitated further revision of the wartime safety organisation. T.A.S.S.O. was accordingly reviewed in Dublin in April 1942 by representatives of the Governments of Canada, United Kingdom, U.S.A. and Eire and by the airline operators British

Overseas Airways, Pan American Airways, American Export Lines and Irish Airlines. The organisation was further reviewed at Ottawa and Washington in the same year. The agreed procedure, incorporated in a new edition of T.A.S.S.O., constituted the civil meteorological arrangements until the end of the war. So far as the United Kingdom was concerned they applied to transatlantic aircraft operating to and from Hurn and Poole through Shannon.

In 1941 B.O.A.C. were entrusted with the operation of a North Atlantic ferry service. This service operated chiefly on the direct route between Prestwick and Newfoundland or from Labrador via Iceland to Prestwick. Aircraft of B.O.A.C. operating between Prestwick, Newfoundland and Montreal were catered for by the meteorological organisation which had been developed during the war to meet the requirements of the big volume of military traffic flying between those places. This organisation, generally referred to as M.O.O.F., was basically the same as T.A.S.S.O., but elaborated and modified in certain respects to meet the special problems of high density of traffic. In particular arrangements were devised to permit of a choice being made as to whether the Northern route via Iceland, the direct route, or the Southern route via the Azores offered the most favourable meteorological conditions on any particular occasion.

It was essential for the operation of the transatlantic air services that the method of transmitting data, route and landing forecasts, and amendments thereto, between North Atlantic bases should be speedy and reliable in all circumstances. A system of multi-addressed, point-to-point, W/T exchanges was developed between Dorval and Prestwick; the messages, in addition to being received at the two main exchange bases at Prestwick and Dorval, were received at Gander (Newfoundland), Goose Bay (Labrador), Iceland, Bermuda and Lagens (Azores). When conditions for W/T transmissions were bad, the messages were sent by high speed cable.

The meteorological organisation over the Atlantic was most highly developed because of the difficult and unique nature of the route. The basic organisation for other routes was broadly the same, though lack of communication facilities prevented the full exchange of information, and the organisation relied on broadcast transmissions instead of point-to-point transmissions.

The Formation of the Provisional Civil Aviation Organisation (P.I.C.A.O.)

When it became clear that the war would be decided in favour of the Allies within measurable time, and that the U.S. civil aviation, which had previously been largely confined to the Western Hemisphere, would be extended and become prominent in other continents, it was necessary to consider what regulations should govern international civil flying. The seat of the International Commission for Air Navigation was in Paris and was inaccessible. As the League of Nations was to be replaced by another organisation, it was a natural corollary that the Commission for Air Navigation should also be replaced by another organisation. Accordingly, a conference was called at Chicago in November 1944 to consider the preparation of an agreement which would form the basis of a world wide organisation. The final act of the Chicago conference contains several technical annexes, one of which is entitled 'Meteorological Protection of International Aeronautics'. This annexe is based largely on

Annexe 'G' of the International Commission for Air Navigation, the 'Reglement' developed by the Aeronautical Commission of the International Meteorological Organisation at Berlin in 1939, and on procedures developed and tested during the war itself.

Meteorology Examinations for Civil Aircraft Navigators' Licences and for B Licences during the War

The examinations for civil aircraft navigators' licences Class 1 and 2 and 'B' licences, ceased on the outbreak of war but were resumed in 1940 although they were held less often and there were fewer candidates than before the war. For example, in 1942 two 1st Class and four 2nd Class examinations were held, the number of candidates at each examination being usually about ten. The number of 'B' licence examinations in the early years was small, but increased in 1944 to five or ten a month.[1]

The papers were set and marked by the Meteorological Liaison Officer at the Civil Aviation Directorate, Bristol, until he was withdrawn in January 1941, after which the work was done by officers at the Meteorological Office. These officers also marked the scripts written at examinations held at Cairo and in South Africa. There was no modification in standards until March 1944 when special wartime licences were introduced. A wartime first class licence was granted on what, so far as meteorology was concerned, was substantially the second class syllabus, but holders of the wartime first class licence would have to take the full peace time examination after the war if they wished to maintain the licence.[2] In the examination, greater emphasis came to be placed on climatology than had hitherto been the case.

Discussions began in 1944 on the syllabuses for civil licences to be adopted after the war. The Meteorological Office was anxious to maintain a high standard of examination in meteorology against a certain amount of suggestion from outside the Air Ministry that it was too high. Discussions also took place from time to time on the exemptions from civil licences to be given to the graduates of various R.A.F. courses. Care had to be taken to grant exemptions only to those who had passed an R.A.F. examination of the same scope and standard. Some difficulty was caused by the issue in 1941 of an Air Ministry Order[3] on the subject without consultation with the Meteorological Office. The order was not formally rescinded during the war, but it was arranged for all applications by individuals for exemption to be referred to the Meteorological Office which was thereby enabled to ensure that only properly qualified officers were exempted from examination.

[1] A.M. Files A.603198/43, 684454/37, A.148935/40.
[2] A.M. Pamphlet 44.
[3] A.M.O. A.891/41.

CHAPTER 18

CO-OPERATION WITH DOMINIONS AND ALLIES

Dominions

During the war, contact was maintained with the Dominions on all matters of mutual interest particularly in regard to questions concerning codes, cyphers and the general security of meteorological information. An exchange of research programmes and information regarding meteorological instruments was arranged. Representatives of the United Kingdom and Dominion meteorological services worked together on such bodies as the Combined Meteorological Committee in Washington and the Allied Meteorological Committee for South East Asia.[1]

Very close liaison was maintained with the Canadian Meteorological Service, to facilitate which, particularly in regard to the meteorological requirements of the Empire Air Training Scheme, a Meteorological Office Liaison Officer was appointed to the United Kingdom Air Liaison Mission in Ottawa. In fact, the provision of meteorological facilities for the various R.A.F. Training Schools in Canada was a combined effort. The provision of meteorological facilities for Ferry and Transport Command was another example of successful team work on the part of both Services, particularly on the North Atlantic route ; in this connection, representatives of the Canadian Meteorological Office made several visits to the Meteorological Office and an exchange of forecasters was arranged. The Canadian Meteorological Service gave valuable aid in negotiations with the United States authorities, before America's entry into the war, in the supply of forms, in providing facilities for the meteorological reporting ships and in many other ways. In return, the Meteorological Office helped to provide meteorological facilities for Canadian Army and R.C.A.F. units in the United Kingdom.

Although liaison with the Australian and New Zealand Services did not need to be so close as with the Canadian service, there was full co-operation throughout the war. An exchange of literature, forms and syllabi ensured co-ordination in regard to the provision of meteorological facilities for Training Schools under the Empire Air Training Scheme. Co-operation was also effected in regard to the meteorological organisation on the Ceylon—Australia air route ; in this connection the Senior Meteorological Officer, H.Q. No. 222 Group, Ceylon, visited Australia in 1943 to arrange for the exchange of advisory forecasts and the Australian Meteorological Service set up a reporting station in the Cocos Islands. Representatives of the Australian and New Zealand Meteorological Services occasionally visited the Meteorological Office. At a Conference in Manila in June 1945, representatives of these services, the Chief Meteorological Officer, A.C.S.E.A. and other Allied meteorologists co-ordinated the Allied meteorological services in the war against Japan. On passing through Australia to and from this conference, the C.Met.O. A.C.S.E.A. discussed

[1] A.M. File S.54956.

matters of mutual interest with the Australian Meteorological Service. In March 1945, when Transport Command had set up a Wing at Sydney (Australia) an officer from the Meteorological Office was sent out as a liaison officer and worked closely with the Australian Meteorological Service.

As in Canada meteorological facilities for transferred R.A.F. Training Schools were provided at first jointly by the United Kingdom and South African Meteorological Services and arrangements were made for instruction and procedure to be in accordance with a uniform practice. Close co-operation with the meteorological service of the S.A.A.F. was also effected in actual theatres of operations.

Allies

France

At discussions with representatives of the Office National Meteorologique of France in September 1938, it was agreed that the efficient functioning of both the British and French meteorological services in war necessitated the exchange of liaison officers between Paris and London. This agreement was based on an appreciation of the fact that, with the dislocation of the system of international broadcasting of meteorological information, and the urgent continuing need of the forecasting services for observations and reports, a number of problems of great complexity would arise, necessitating the closest collaboration between the two meteorological services.[1]

When the international situation again deteriorated, a liaison officer was sent to the Office National Meteorologique in Paris on 29 August 1939. He had had considerable experience in the Meteorological Office and, as he was a Volunteer Reservist, he was mobilised forthwith. In September, a French liaison officer was sent to London, although it was later found that this officer was largely redundant.

The work of the Meteorological Office Liaison Officer covered the whole field of activities of mutual interest, the problems he dealt with included the following :—[2]

(*a*) Arrangements for the exchange of British and French observations.

(*b*) Arrangements for supplying both British and French observations to the British Meteorological Service in the Field.

(*c*) Arrangements for securing meteorological information from neutral countries which had ceased to broadcast.

(*d*) Attempts to secure the suppression of meteorological broadcasts from other neutral countries such as Iceland, Azores and Spain, at the same time arranging to secure the reports solely for the use of the Allies.

(*e*) Arrangements for obtaining reports from the North Atlantic.

(*f*) Special meteorological arrangements for civil aviation.

(*g*) Co-ordination of action to introduce meteorological security in British and French Dominions and Colonies in various parts of the works, as required.

(*h*) Co-ordination of action to prevent compromising each others' cyphers.

[1] A.M. File S.38063.

[2] A.M. File S.56597.

(*i*) Arrangements in connection with top secret sources of information.

(*j*) Formulation of agreed procedure for communicating meteorological information to neutrals and special countries.

(*k*) Exchanges of climatological memoranda and other technical data.

(*l*) Negotiations regarding the use of French radio-sonde equipment in the United Kingdom and the British zone in France.

Until the British withdrawal from France, the British Meteorological Liaison Officer was a vital link between the Office National Meteorologique and the Meteorological Office ; during the latter stages, when conditions in France were becoming chaotic, and the H.Q. of the Office National Meteorologique underwent successive moves, he succeeded in maintaining contact between the two services until the last moment.

In addition to the day to day liaison effected through the Meteorological Office Liaison Officer, a number of major conferences were held between the two Services at which the Chief Meteorological Officer in the Field was represented. At these conferences all aspects of co-operation were discussed and the general lines of future collaboration decided.

After the fall of France, liaison was maintained with the Free French authorities and, later, with the ex-Vichy authorities in Middle East, Africa and France.

The United States of America[1]

There was little direct liaison between the Meteorological Office and the Weather Services of the United States at the beginning of the war. In negotiations which took place at that time on matters of mutual interest, the Controller of the Canadian Meteorological Service acted as intermediary, with the British Air Attaché in Washington holding a watching brief.

A senior member of the Meteorological Office staff visited Canada in September 1940 to deal with a number of questions, mainly arrangements for the Empire Training Schemes, and advantage was taken of the opportunity to visit Washington to discuss current problems including arrangements for transatlantic flying and meteorological organisation in the West Indies. With that exception, liaison continued to be effected through the Meteorological Office Liaison Officer, who had been posted to Canada in November 1940, and the Canadian Meteorological Service until the spring of 1941, when a U.S. Meteorological Officer was attached to the office of the U.S. Naval Air Attaché in London. This new channel, which remained until the end of the year, was used for dealing with the numerous complex questions which arose during the interval between the enactment of Lend-Lease and the entry of the United States into the war.

In the summer of 1941, an officer of the U.S. Army Weather Service visited the United Kingdom. He and his naval colleagues were given every facility to study the war organisation of meteorology in this country.

Representatives of the U.S. Navy, U.S. Army and the U.S. Weather Bureau met in Washington in August 1941 to discuss meteorological problems with the Controller of the Canadian Meteorological Service and the Meteorological

[1] A.M. Files S.68645 and S.100840.

Office Liaison Officer to Canada. Thereafter, relations between the latter and the U.S. Services, particularly the Weather Bureau, were on a more personal basis. In April 1942, when the post of Meteorological Office Liaison Officer (M.O.L.O.) in Washington was established, the officer in question was transferred from Canada. Although he was attached to the R.A.F. Delegation his office was in the Headquarters of the Western Bureau. From then onwards close co-operation with all three U.S. Services was maintained throughout the war, the M.O.L.O. Washington being used to the full both by the Meteorological Office and the U.S. Meteorological Services, except on matters of high policy, or of a personal nature. Very good relations were established with all three U.S. Services.

Liaison on purely Naval questions was effected by a representative of the Naval Meteorological Service of the Admiralty attached to British Admiralty Delegation, but all questions of general application were dealt with by the M.O.L.O. Washington, in consultation with the Naval Liaison Officer as necessary.

In 1944 co-operation with the U.S. was extended to cover the important field of short wave propagation and liaison on the meteorological aspects between the J.M.R.P. sub-committee in the United Kingdom and the Burrows Committee in the U.S.A. was through the medium of the M.O.L.O. Washington.

A full and continuing exchange of views was maintained on all questions of a policy character affecting United Kingdom and the U.S.A. covering a wide range of subjects such as :

(*a*) Synoptic meteorology.

(*b*) Security of meteorological information.

(*c*) Cyphers—types, strength, etc.

(*d*) Instruments.

(*e*) Arrangements for air routes.

(*f*) Climatology including synoptic climatology.

(*g*) Meteorological research.

(*h*) International questions, *e.g.*, those relating to the I.M.O.

Publications of all types, including many classified as Top Secret, were also freely exchanged. They included all types of meteorological cyphers, publications dealing with the synoptic climatology of all parts of the world, and with synoptic meteorology, *e.g.*, M.O. handbooks, and descriptions and specifications of meteorological instruments.

Co-operation was extended to the exchange of meteorological instruments. In particular, the U.S. received samples of the Dobson dew-point hygrometer and the M.O. theodolite, while the Meteorological Office received a sample of the Anderson wired sonde, developed by Professor Anderson of the Washington State College, to make soundings of the atmosphere at frequent intervals of height in the lowest 1,000 feet or so.

U.S. meteorological co-operation with nations outside the Western Hemisphere had been limited before the war ; many U.S. meteorologists in the U.S. Forces had a very hazy knowledge of the International Meteorological Organisation, and some had never even heard of it. At the outset, therefore, there was considerable opposition to the traditions and viewpoint of European

meteorologists, aggravated perhaps by the ' newness ' of the partnership and by the suspicion of some Americans that the British would try to foist on them their views, which, in many cases, the Americans regarded as complicated and impracticable. These difficulties were gradually overcome and by the end of 1944 co-operation on all questions had reached a maximum consistent with departure from the ideal due to differences of technical and scientific outlook and to national character.

One particular phase of co-operation was the help given to British meteorological offices in the West Indies (Bermuda, Nassau, Jamaica, Trinidad). The Americans gave the utmost aid in maintaining these offices with certain categories of technical stationery and instruments from 1942 to 1945, at a time when the efficient functioning of these offices was seriously jeopardised by heavy losses of consignments from the United Kingdom owing to enemy action.

As the war continued, co-operation between the Meteorological Office and the U.S. Services assumed a scale quite unforeseen in early 1942, and embraced almost every aspect of meteorological activity by the end of 1944. This large scale co-operation, involving many minute details, could not have been achieved without personal contact, and the decision to post a Meteorological Office Liaison Officer to Washington was fully justified.

U.S.A.A.F.

At the request of H.Q. Bomber Command in April 1942, a senior officer was deputed to visit H.Q. VIII Bomber Command, U.S.A.A.F. early in May to discuss with the Commanding General the assistance which would be required of the Meteorological Office. It was immediately clear that the U.S.A.A.F. Weather Section in the United Kingdom would depend greatly on the parallel British organisation for various essential help and facilities. At this time the U.S. Weather Service personnel in the United Kingdom consisted of a small advance contingent of some 30 officers and enlisted men. Arrangements were made for most of these to be attached to meteorological offices at Group H.Q. and stations in Royal Air Force Bomber Command to acquire familiarity with British procedure, a substantial part of which had been developed during the war to suit the special requirements of the time. An officer of the Meteorological Office was attached provisionally to H.Q. VIII Bomber Command in June 1942.[1] Director of Telecommunications, Air Ministry, was advised in general terms that units of the U.S.A.A.F. Weather Service would require to be included in the Meteorological Office teleprinter network centred at Dunstable and to receive facilities similar to those provided for meteorological offices at Royal Air Force formations and units. The specialised procedure, including codes supplementary to the International Meteorological Code, which had been developed by the Meteorological Office since the outbreak of war made it essential that copies of relevant Meteorological Office publications, orders and technical instructions should be supplied without delay to the advance party of the U.S. Weather Service.

From these and other early contacts, it was learned that the U.S.A.A.F. Weather Service and the British Service differed in organisation and in meteorological technical procedure. The U.S.A.A.F. realised that adequate

[1] A.M. File S.82889.

liaison arrangements were desirable if their Weather Service was to operate effectively. Following discussions between the Director, Meteorological Office and the Staff Weather Office, U.S. Eighth Air Force in June–July 1942 it was agreed to provide officers of the Meteorological Office for liaison duty, on long term attachment to H.Q. Eighth Air Force and VIII Bomber Command (and, in principle, to other U.S. Command H.Q.) and on attachment of up to two months at specified Wings (= R.A.F. Groups) and Groups (= R.A.F. Stations). In the event, a liaison officer (M.O.L.O.) was maintained at Eighth Air Force H.Q. from August 1942 to January 1945, at VIII Bomber Command until 31 November 1942; while an officer was provided at H.Q. Ninth Air Force (the counterpart of 2nd Tactical Air Force, R.A.F.) from February to December 1944. Liaison officers attached to Wings and Groups were withdrawn, usually within two months, as soon as the U.S.A.A.F. weather station was working smoothly and the U.S. personnel had become experienced in British procedure for the reporting and distribution of meteorological information. In many cases liaison officers proceeded to carry out similar functions at other formations established, or at stations occupied by, the U.S.A.A.F. The need for formal liaison at Wings and Groups had practically ceased by March–April 1943, though one officer continued in these duties at a U.S.A.A.F. Weather Service Training School, until January 1944.

The duties of a liaison officer attached to a U.S.A.A.F. Weather Unit varied, as to emphasis on individual items, according to location, time and other circumstances. It is not possible to particularise all the innumerable points which arose between two services situated as were the U.S.A.A.F. Weather Service and the British Meteorological Office, but the following bald summary of duties issued at the time (together with other items of guidance) may be noted :—

(*a*) Explanation of Meteorological Office organisation and procedure generally to U.S.A.A.F. Weather Officers and other personnel.

(*b*) Advice on the setting up and management of British instruments.

(*c*) Advice on the use of British special codes, the making of observations, the evaluation of Airfield Weather Fitness Number, and the preparation of reports for transmission to the British Central Forecasting Office. (Certain liaison officers assisted in the preparation of a 'Digest of British Codes' for use by the U.S.A.A.F.)

(*d*) Methodical exposition of Meteorological Office Synoptic Instructions, with special reference to items not of everyday occurrence.

(*e*) Instruction of U.S.A.A.F. weather personnel in classes if so requested by Weather Officers.

(*f*) At a new station, to assist in expediting the installation of cloud-searchlight, visibility lights and teleprinter.

(*g*) To place at disposal his technical knowledge of weather in the United Kingdom and adjacent areas, and to advise U.S.A.A.F. staff as to publications and other documents for reference.

(*h*) To advise generally within his competence and province, on matters which may arise in the running of the station.

In the earlier phases, liaison officers were asked by the U.S.A.A.F. for their opinion on weather for projected flight operations, but the necessity for this lapsed as American colleagues gained experience of European weather. It

was understood from the start that while U.A.S.A.F. should receive the basic current meteorological information available to the British Service, along with the derived information consisting of technical analyses and guiding forecasts, the U.S.A.A.F. Weather Service was responsible for giving advice for U.S.A.A.F. operations.

As time went on and as liaison officers were withdrawn from lower U.S.A.A.F. formations, the bulk of the normal liaison work naturally devolved on the M.O.L.O. at H.Q. Eighth Air Force (later U.S. Strategic Air Force). He represented the Meteorological Office at the U.S. H.Q. in relation to practically all meteorological matter pertaining to the U.S. Weather Services in the United Kingdom, and maintained contacts with relevant officers or branches of the Meteorological Office accordingly. One of his routine responsibilities was to indicate the distribution to be made to the U.S.A.A.F. of meteorological Confidential or Secret Documents, Meteorological Office Orders, Synoptic Instructions (including 'S' series) and Synoptic Divisions Technical memoranda.[1]

The arrangements for liaison worked satisfactorily. They were necessary and proved advantageous to the Meteorological Office as well as to the Weather Service of U.S.A.A.F. It was to the common interest that both Services operating in the same area to the same end should, as far as possible, follow a uniform and common procedure in matters affecting both, and that there should be machinery for ensuring ready discussion and ultimate agreement on modifications in technical procedure desired by either party to meet changing requirements. Day-to-day liaison at the levels described was supplementary to direct discussion of policy and other major matters which took place as need directed between the Staff Weather Officer (later, Director of Weather Services) H.Q. U.S.A.A.F. and the Director of the Meteorological Office or his more senior officers. In addition, there were frequent personal contacts at various levels between personnel of the two services for discussion of technical matters and exchange of views.

A captain of the U.S.A.A.F. was attached to the Meteorological Office in November 1943 for liaison duties. This arrangement lapsed after a comparatively short period. Liaison officers of the U.S.A.A.F. Weather Service were attached for a time to the meteorological offices at Stornoway, Prestwick and St. Eval, particularly in connection with U.S. air transport operations.

From April to July 1943, the meteorological office at H.Q. R.A.F.N.I. was staffed jointly by British and U.S. personnel and acted as parent meteorological centre to all R.A.F. and U.S.A.A.F. units in Northern Ireland. A similar integration, or close association, of British and U.S. meteorological sections was developed at the joint U.S.–British Airborne Command Post in June 1944 and continued, with modifications, later in 1944 and early 1945, at H.Q. First Allied Airborne Army. There was also close collaboration between British and U.S. meteorological staff at SHAEF and H.Q. A.E.A.F. Although these are the main instances of joint-working of staffs located together, there was close co-operation between British and U.S. forecasters (not located together) concerned with giving advice for joint operations by the two air forces. This was effected by telephone conferences between the meteorologists at the main U.S.A.A.F. and R.A.F. formations involved, *e.g.* VIII Bomber Command and its Wings

[1] A.M. File S.83663.

on the one hand and R.A.F. Fighter Groups on the other, often with the Central Forecasting Office participating, at which the meteorological appreciation and forecasts relating to the joint operations were co-ordinated. Meteorological conferences of this nature had been developed before 1942 in R.A.F. Bomber Command.

In the observational field, the U.S.A.A.F. contributed to the common cause by establishing upper air (radio-sonde, radar-wind) units and by carrying out meteorological reconnaissance flights, thus supplementing similar British activities.

After *ad hoc* action had been taken in June 1942 to meet the immediate needs of the small contingent of the U.S.A.A.F. Weather Service in the United Kingdom the nature and probable extent of further requirements for supply of meteorological instrumental equipment stores, official publications, organisational and technical instructions were discussed with the U.S.A.A.F. It was found that British meteorological instruments would be required to augment, or substitute temporarily, instrument equipment which was to be sent from America and of which some was to be kept in reserve for use when U.S.A.A.F. units became mobile. The supply arrangements, made in conformity with S.D.348 and A.M.O. A.937/42 were embodied in an M.O. Order, which provided that British meteorological offices at airfields taken over by the U.S.A.A.F. should be handed over as going concerns, with reservations as to the disposal and re-issue of secret and confidential documents. Supplies of instruments, equipment, publications and forms for new stations occupied by U.S.A.A.F., and future issues for other stations were to be demanded from the Meteorological Office by H.Q. Eighth Air Force. Equipment, stores and publications were normally sent direct by Meteorological Office, or A.P.F.S., to the unit requiring them. The Meteorological Office undertook to arrange with Air Ministry Works Department for standard cloud searchlights and visibility lights to be installed at any airfields coming into occupation by U.S.A.A.F. at which arrangements were not already in hand.

Meteorological teleprinter communications were provided, following discussions between British and U.S. meteorological and signals representatives, mainly according to the general plan adopted by the Meteorological Office, viz., normally two channels from the Central Forecasting Office to meteorological offices at headquarters of Commands, Groups (U.S. Divisions or Wings) and thence one channel (sometimes two) to airfields. Certain modifications were introduced to meet U.S.A.A.F. preferences and organisational requirements. The number of U.S.A.A.F. Weather Units ultimately included in the teleprinter network was over 70.[1]

In February–March 1945, H.Q. U.S. Strategic Air Force being then located on the Continent, it was agreed that the general situation made it unnecessary to replace the British meteorological liaison officer withdrawn from the American H.Q. in January and that future matters of interest could be dealt with in correspondence between the Director of the Meteorological Office and the Director of Weather Services, U.S. Strategic Air Forces in Europe or between their respective staffs.

Co-operation with the Weather Services of the U.S.A.A.F. in the various theatres of operations overseas is described in other chapters.

[1] A.M. File S.83657.

Russia

Unlike other Soviet Government Departments, the Hydrometeorological Service (G.M.S.) of the U.S.S.R. co-operated fully almost from the entry of Russia into the war. The reason for this unusual attitude is not clear, but several contributory factors can be suggested :

(*a*) The directorate of the G.M.S. were more accustomed to the idea of international co-operation than was normal in Russia, because of the peace-time activities of the International Meteorological Organisation.

(*b*) The Director General of the G.M.S., who was directly responsible to the General Staff, appeared to enjoy a fairly large degree of autonomy.

(*c*) Generally, the data which the Meteorological Office had to offer were more valuable to the G.M.S. than the G.M.S. data were to the Meteorological Office.

Whatever the reasons, the G.M.S. was the one Soviet Department which was authorised to negotiate directly with the British Military Mission in Moscow, and on a number of occasions the members of the Mission commented on the co-operative attitude of the G.M.S.[1] This was purely relative, however, and did not mean that the dealings of the G.M.S. with the British authorities in Moscow and with the Meteorological Office were entirely untrammelled and without reserve. The general guiding principles of Russian policy were always adhered to, particularly the principle of strict reciprocity, which was insisted upon wherever it could be applied, *e.g.* the number of station reports included in the routine synoptic exchanges.[2]

The Air Section of the British Military Mission in Moscow (No. 30 Mission) was the normal channel for negotiations between the G.M.S. and the Meteorological Office. There was little personal contact between the personnel of the two services and, as Russian and British services did not operate in the same theatre, there was no need for the close collaboration which was developed between the Meteorological Office and the U.S.A.A.F. Weather Service. The main fields of co-operation between the two services were the routine exchanges of synoptic data for general forecasting purposes, and the exchange of reports, analyses and forecasts in connection with flights to and from Russia. The arrangements for the routine exchanges were comparatively straightforward and were dealt with almost entirely through No. 30 Mission. The *ad hoc* meteorological arrangements for the first flights were also arranged through No. 30 Mission, but a more elaborate organisation on the lines of the Meteorological Office's 'Meteorological Organisation for Overseas Flights' was later developed during visits of a member of the Meteorological Office staff to Moscow in 1942 and of a G.M.S. representative to the United Kingdom in 1943. Subsequent renewals and modifications of these arrangements were effected through No. 30 Mission.

Apart from the synoptic exchanges, there were intermittent exchanges of climatological data and general information on forecasting technique. Copies of Meteorological Research Committee papers, which had been approved for

[1] A.M. Files S.77453/II and S.69297.

[2] From the meteorological viewpoint, this was rather ludicrous as it took no account of the relative areas covered by the reports, or of meteorological factors such as local variability of weather or stability of climate.

circulation, were supplied to the G.M.S., as were specifications, blue prints and specimens of instruments developed by the Meteorological Office. During the period under consideration, the G.M.S. benefited much more than the Meteorological Office from these exchanges; the latter hoped, by supplying the technical information, to obtain an increased supply of data from Russia, but this was necessarily a long term policy. The language difficulty prevented the Meteorological Office from benefiting fully from the exchange as the publications and papers supplied by the G.M.S. were in Russian and, whereas a considerable number of the senior officials and technical personnel of the G.M.S. had some knowledge of English, the reverse was not the case. The merits of any particular publication could not be decided until it had been translated, and the translation of numbers of lengthy scientific papers was, of course, out of the question.

The Meteorological Office also acted as intermediary between the G.M.S. and a number of British authorities interested in cosmic data. Observations of terrestrial magnetism from observatories of the G.M.S. were supplied to the Astronomer Royal, and data from the same sources were forwarded to the Department of Scientific and Industrial Research.[1]

The posting of a Meteorological Liaison Officer to Moscow was discussed a number of times but it was decided that there were insufficient grounds for this as the members of No. 30 Mission were able to deal with general meteorological liaison matters when given the necessary guidance from Air Ministry. The only direct liaison occurred during brief visits made by members of both services. Three Russian meteorologists visited the United Kingdom early in 1942[2], and were given every facility for studying the organisation and working methods of the Meteorological Office. They visited the meteorological offices at Bomber Command H.Q., Fighter Group (No. 11) H.Q. and at representative stations including Prestwick. They were also given the opportunity of discussing the aspects of meteorology in which they were interested with their opposite numbers in the Meteorological Office.

In connection with the meteorological arrangements for flights between the United Kingdom and Russia, the Head of the North Atlantic Branch of the Meteorological Office visited Moscow with the first of a series of B.O.A.C. flights in October 1942, and a representative of the G.M.S. visited the United Kingdom early in 1943. During the Yalta conference, a British forecasting officer was stationed at Saki and worked with the local G.M.S. office, and in 1944 a Russian forecaster was stationed at the meteorological office in Iceland to deal with the delivery flights of Catalinas with Russian crews.

By the autumn of 1944 the routine exchanges between Moscow and the United Kingdom had become unsatisfactory from the British standpoint because of a number of modifications introduced by the G.M.S. at the request of the U.S. Naval Meteorological Liaison Officer in Moscow, and a member of the Meteorological Office staff was posted to No. 30 Mission for a few weeks to deal with this and a number of other problems which had arisen. The question of maintaining a Meteorological Liaison Officer permanently in Moscow was again raised by the Head of the Air Section of the Mission, but it was decided that it was impossible to spare a suitable member of the Meteorological Office staff and the meteorological officer was recalled at the end of September.

[1] A.M. File S.69297.

[2] M.S. 18/43.

Other Allies

Particular mention needs to be made of the services rendered by the Polish section of the Meteorological Branch of the R.A.F.V.R. which, under the command of Wing Commander K. Zacharewiz, not only provided meteorological facilities for Polish Army and Air Force units in the United Kingdom and overseas, but gave help at several British meteorological offices where there were shortages of staff. The Polish meteorological personnel worked in very close harmony with their British colleagues and fully conformed to British procedure and practice.

Valuable help was likewise rendered by the Belgian section of the Meteorological Branch of the R.A.F.V.R. under the command of Wing Commander Baron Le Dorlodot. Reference is made elsewhere to the co-operation of Wing Commander Dorlodot in developing the meteorological service in the Belgian Congo to meet the requirements of civil aircraft operating from Lagos to the Middle East, and to the joint steps which were taken to re-establish the Belgian national meteorological service.

Co-operation with Norwegian meteorologists in respect of Jan Mayen and in Norway itself is referred to elsewhere, as is the work of the distinguished Norwegian meteorologist, Dr. S. Petterssen in the Upper Air Section of the Central Forecasting Office.

The Combined Meteorological Committee

With the entry of the United States into the war in December 1941 and the spread of hostilities to the Far East and Pacific, very close collaboration between the U.S.A. and the British Commonwealth was necessary if their respective war efforts were to be used to the full. Accordingly, the Prime Minister of Great Britain and the President of the United States agreed on the formation of a Combined Chiefs of Staff Committee, to be located in Washington, to plan and co-ordinate operations on a combined basis against Germany and Japan.[1] Various Boards and Sub-Committees were set up to deal with technical and supply questions, and in January 1942 the U.S. Defence Meteorological Committee recommended to the U.S. Joint Chiefs of Staff the formation of a Combined Meteorological Committee, under the Combined Chiefs of Staff, in order to achieve the maximum collaboration on meteorological questions. This was imperative, for many U.S. practices in synoptic meteorology differed vastly from those in Europe and in many parts of the British Commonwealth. The U.S.A., although a member of the International Meteorological Organisation, had not, on many points, conformed to I.M.O. Resolutions, and on many questions there was a wide difference of opinion between the U.S.A. and Great Britain. Collaboration on meteorological matters was clearly of paramount importance.

Accordingly, the U.S. Joint Chiefs of Staff approached the British Chiefs in Washington and in January 1942, the British Chiefs of Staff in London were asked to consider the formation of a C.M.C. in Washington.[2] It was proposed that the Committee should plan co-ordination and co-operate in meteorological matters affecting current war operations such as :

(*a*) Exchange of weather information.

(*b*) Uniform system of reports, elimination of duplicate summaries and simplification of methods.

[1] M.S. 374/46.

[2] Signal J.S.M. 43.

(*c*) Preparation of requisite meteorological codes and cyphers for joint use, including uniform aircraft landing weather code.

(*d*) Plans for new or additional services.

(*e*) Exchange of information on methods and new development.

(*f*) Authentication of weather information, transmitted by radio and of requests therefor.

(*g*) Recommendation on restriction on, and censorship of, weather information.

(*h*) Recommendation on contents, time, power frequency and classification of radio weather broadcasts.

The British Chiefs, after consultation with appropriate Departments in the Air Ministry and Admiralty, agreed to the formation of the C.M.C. and in April 1942 a Meteorological Office representative was sent to Washington to serve on the Committee. There was already in Washington a British Admiralty Delegation on whose staff was a member of the Naval Meteorological Service who was appointed to represent the Admiralty. A good deal of the initial spade work associated with the formation of the Committee was successfully accomplished by him.

It was originally proposed that the Meteorological Services of the U.S.A., United Kingdom, the Dominions, China, U.S.S.R. and India should be represented on the Committee. The U.S.S.R. could not accept the invitation, however, as they were not at war with Japan, and China not having a State Meteorological Service in the sense that it represented all the country, decided against representation. In any case, it is doubtful if at that time a suitable representative could have been spared from his duties in China. The D.G.O., India arranged with D.M.O. that the latter's representative should speak for India. Consequently the final membership took the following form :

Three Members from the U.S.A. (U.S.W.B., U.S. Navy, U.S. Army).

Two Members from the U.K. (N.M.B. Admiralty, M.O. Air Ministry).

One Member from Canada.

One Member from Australia.

One Member from New Zealand.

One Member from South Africa.

Thus the Committee was in effect a U.S.–British Commonwealth body, and for a long period, particularly towards the close of the war, was a U.S.–United Kingdom affair. None of the Dominions was able to appoint a full-time member, but Canada was able to keep close touch and had a representative at a great many of the meetings ; Australia, New Zealand and South Africa were represented at meetings from time to time, especially during 1942 and 1943. These Dominions and India were kept fully informed of all questions under discussion. Copies of agendas, papers and minutes were forwarded to their respective Directors who were thus able to study the matters under consideration by the Committee. They kept the United Kingdom members fully briefed as to their views by letter and signal, so that a completed U.S.–British Commonwealth viewpoint was obtained on most questions, particularly on major questions.

A charter of the C.M.C. was provisionally drawn up at its first meeting in April 1942, based on the proposed terms of reference to which only minor amendments were made. The Charter was duly approved by the British Chiefs of Staff on the condition that agreed decisions of the C.M.C. would be implemented by the Directors of the Meteorological Services concerned. No decisions were taken on a majority basis ; there had to be unanimity, although in some instances, Australia and New Zealand indicated that if their views constituted a part of a minority, they would, when straightforward alternatives were involved, abide by the views of the majority.

The chairmanship of the C.M.C. was not held permanently by one individual. It changed at each meeting, U.S. followed by United Kingdom and so on, and was held in turn by the three U.S. Members and the two British Members.

The Committee started without sub-committees and was soon smothered in a welter of detail. In November 1942, therefore, a number of sub-committees were formed. At the same time the Charter of the Combined Meteorological Committee was amended. The sub-committee on Weather Communications was by far the most important. It consisted of representatives of the three U.S. Services and the two British Services, but representatives of the Dominions had the right to attend the meetings if they so wished. The representative of the Meteorological Office was the permanent chairman.

The Weather Communications Sub-Committee was constantly in session and, at times, met twice a week although, normally, weekly meetings sufficed. It dealt with the whole field of synoptic meteorology (comparable in scope to the work of the peace-time Commission for Synoptic Weather Information), including all types of symbolic code forms, specifications, times of observation, index numbers, units, collective messages, reconnaissance flights, aircraft reports, etc. In addition it dealt with the whole field of meteorological security, in conjunction with the combined Communications Board, in its various aspects of :

(*a*) Degree of security required in given areas, *i.e.* what type of information could go in clear, depending on the remoteness of the area from the enemy.

(*b*) Cyphers for collective issues.

(*c*) Cyphers for point-to-point transmissions.

(*d*) Cyphers for use by aircraft to send messages air to ground.

(*e*) Cyphers for ground to air messages.

(*f*) Examination of the suitability of cyphers for various purposes both from the point of view of use and depth to which they could be used safely.

As time went on it became necessary to form other sub-committees to meet additional requirements. The following is a list of the sub-committees with the dates on which they were formed :

Weather Communications	3 November 1942.
Research and Development	3 November 1942.
Equipment	3 November 1942.
Weather Plans	3 November 1942.
Liaison	17 November 1942.
Meteorology and Radio Propagation (At first ' Working Committee ')	22 February 1944. (Title changed 1 August 1944.)

The Research and Development Sub-committee did not meet very often, but was instrumental in arranging a complete interchange between the United Kingdom and U.S.A. of all research programmes. In particular, most of the M.R.P.s of the Meteorological Research Committee were made available to the U.S. Services. The results of these researches were much used by the U.S. Services, and many points of difficulty in their own researches and techniques were cleared up by their having access to the British findings. This particularly applied to radio-sonde questions and techniques relating to the use of upper air data and their analysis.

The Equipment Sub-committee was largely concerned with the allocation of priorities regarding the supplies of U.S. instruments to Meteorological Services of the British Commonwealth. In this way, large numbers of radio-sonde transmitters and receivers were made available to Australia and South Africa. Attempts to obtain these vital instruments through non-meteorological channels invariably ended in failure.

The Weather Plans Sub-committee dealt with large scale planning usually of a global character. One such plan was that of co-ordinating the density and location of radio-sonde stations over most of the world and obtaining agreement in respect of certain areas.

The C.M.C. recognised the value of Regional Committees in the various theatres of war and encouraged their formation, but only one such Committee was in being for any length of time. This was the Allied Meteorological Committee, South-East Asia, with Headquarters in New Delhi and on which sat representatives of D.G.O. India, the Royal Air Force Meteorological Service in India, N.M.B. Admiralty, and the U.S.A.A.F. This Committee removed chaos in its own theatre and achieved a large measure of co-ordination with the Southwest Pacific theatre. A.M.C.O.S.E.A. was successful because it strove to follow the principles and lines along which the C.M.C. was thinking and because it was prompt in implementing decisions of the C.M.C.

In addition to the good work accomplished by A.M.C.O.S.E.A., a *permanent* Theatre Committee, much success was achieved by the Pacific and Southwest Pacific Theatre Conferences held at Sydney in March 1944, and Manila in June 1945. At both these conferences representatives of the U.S.A. and the British Commonwealth tackled the general field of meteorological problems with special reference to those areas, and their agreed recommendations which were normally based on C.M.C. agreements or discussions, were forwarded to Washington for examination and comment and subsequent approval, before being implemented.

Thus, both directly and indirectly the C.M.C. exerted a great influence all over the world in practical meteorological problems affecting the prosecution of the war. As the Armies, Navies and Air Forces of the U.S.A. and British Commonwealth were fighting side by side in every theatre and were dependent on each other for meteorological data, it was essential that, in order to avoid confusion and chaos, there should be the maximum of co-ordination and co-operation on meteorological questions. In aiding, in a large measure, to bring this fusion into being and keep it going, the C.M.C. accomplished a most useful task.

CHAPTER 19

FLYING CONTROL

The development of meteorological services for the R.A.F. Regional Control Organisation have been described in Chapter 1. On the outbreak of war, the regional wireless broadcasts were stopped for security reasons. Before the war, the observations for the Regional Control broadcasts had been made by 'weather recorders' who were not members of the Meteorological Office staff. As most meteorological offices kept continuous watch from the outbreak of war and made hourly observations which were broadcast by teleprinter, the 'weather recorders' became redundant and the Control Committee agreed on 16 November 1939 that the Meteorological Office should be responsible for providing meteorological information. Bomber Command agreed that hourly routine reports would suffice, with deterioration and improvement reports as necessary, and that duty pilots would take and transmit weather reports at airfields without meteorological staff. At the same time, the Meteorological Office put forward a scheme for transmitting weather reports in cypher to aircraft which, it was decided, should be discussed by Bomber Command and the Meteorological Office. It was discussed at an Air Ministry conference on 15 January 1940.[1]

In order to use fully landline and other signal services, the Air Ministry decided in May 1940 to transfer the arrangements for giving advice and instructions to aircraft in flight from the existing regional control centres to certain operational Group H.Q. or other centres of communication and to establish airfield control officers at airfields with direction finding or beam approach apparatus.[2] The responsible Air Ministry Branch were provided on 27 May 1940 with lists of meteorological offices available to provide meteorological advice to the control centres.

The next important event in connection with Flying Control as it was now called, was the formation of Central Flying Control in the Operations Room at H.Q. Bomber Command.

Introduction of Fitness Numbers for Central Flying Control

The main function of Central Flying Control was to divert aircraft which could not return to bases in their own groups. An airfield weather map, set up in Central Flying Control, was arranged so that a light at the position of each airfield could be made to change colour according to the fitness of the airfield for landing. The original arrangements provided for half-hourly reports to be made by Flying Control officers when conditions were deteriorating in the terms 'fit,' 'unfit' or 'fit for emergency landing only', but these were modified after an Air Ministry Conference in January 1942.[3] The major decision was that the Meteorological Office should compile a scale of fitness numbers (Fn) taking into account the significant factors for the landing of

[1] A.M. Files S.58973 and 730077/38.
[2] A.M. File S.58973.
[3] A.M. File S.80855.

aircraft. The appropriate figure was to be included in the coded station report sent through the Central Forecasting Office to H.Q. Bomber Command where the meteorological staff would assign the fitness colour in accordance with an agreed scheme and transmit it to Central Flying Control. The transmission of fitness numbers began on 1 May 1942. From that date, meteorological offices also transmitted to Bomber Command a special report when conditions altered so as to change the fitness colour.[1] It was also decided that meteorological staff should be provided at all airfields likely to be used for diversion which were over ten miles from an existing reporting station or had some special feature, that cloud searchlights and visibility lights should be provided at all diversion airfields, and that Flying Control officers should send reports from all those airfields which had no meteorological observers.

Diversion Procedure

Close liaison was maintained between the Meteorological Office, H.Q. Bomber Command and Central Flying Control. On operations when conditions were such that diversion of aircraft to other Groups was expected, provisional diversions were arranged before take-off and final diversions after take-off. The final decision as to the number of aircraft which could be accepted in any Group was taken by Group Air Staff on the advice of the Group forecaster. The remainder were diverted by Central Flying Control acting on Command H.Q. meteorological advice. For this purpose, hourly charts were maintained from which the forecaster determined the best areas for diversion. It was arranged for urgent reports of weather changes to be passed by priority telephone calls from stations to Groups and thence to the Central Flying Control in about five minutes. To achieve this, the second teleprinter channel was used for transmitting to the Central Forecasting Office and thence to H.Q. Bomber Command.

No further important administrative arrangements were made for Flying Control during the war. From time to time, the Meteorological Office received lists of airfields requiring meteorological information for Flying Control and these were taken into account in arranging the distribution of meteorological facilities. Central Flying Control continued at H.Q. Bomber Command until after the end of the war in Europe. In the autumn of 1945 it moved to Uxbridge and changed its name to United Kingdom Diversion Control.

Meteorological Instruction for Flying Control Officers

Courses of instruction for Regional Control Officers were held in the first two years of the war at Boscombe Down, Mildenhall, H.Q. Coastal Command and Oxford. About ten hours of lectures on meteorology were given to each course by the staff of the nearest available meteorological office. No definite syllabus was laid down but the topics covered generally were co-ordination with Meteorological Office, atmospheric pressure and application to altimeters etc., isobars and wind, moisture in the atmosphere, aircraft landing code.

Later, at the end of 1941, a Flying Control School was set up at R.A.F. Station Watchfield and meteorological instruction was given by an instructor of Air Service Training. The syllabus and notes which he used were examined

[1] Synoptic Instruction 76.

by the Meteorological Office and a revised syllabus and set of notes were prepared. The new syllabus was for nine lectures as follows :[1]

- (*a*) and (*b*) Wind, Visibility, Cloud
- (*c*) Pressure
- (*d*) Meteorological Organisation
- (*e*) Reports, forecasts and warnings
- (*f*) Flying on cloud, Icing, Thunderstorms
- (*g*) and (*h*) Meteorological Service for Flying Control ; Reports to aircraft before landing
- (*i*) Sketch of weather map and terms used in forecasts.

The revised notes and syllabus were accepted by the Directorate of Aircraft Safety and Flying Training Command, and put into force on the transfer of the School of Flying Control to Bridgnorth in November 1942. The meteorological instruction to the School at Bridgnorth was taken over by the meteorological officer at the Elementary Air Navigation School there. The School returned to Watchfield in May 1943 and the meteorology instruction was taken over by a navigation officer. It was arranged for a forecaster from H.Q. No. 91 Group, Abingdon, to give a résumé lecture to each course. The passing out examination of the Flying Control School was conducted by the Central Examination Board, Flying Training Command, and a qualifying standard had to be attained in meteorology.

In connection with the transmission of landing reports in UCO code to aircraft by Flying Control officers at airfields with no meteorological staff, it was found necessary in 1944 to prepare a small pamphlet[2] on meteorological observation and compilation of UCO reports for the use of these officers.[3]

[1] A.M. File A.901283/46. [2] A.M. Pamphlet 185.
[3] A.M. Files S.58973 and A.774634/45.

PART III

METEOROLOGICAL INFORMATION TO R.A.F. UNITS OVERSEAS

CHAPTER 20

THE MIDDLE EAST

Meteorological Organisation and Development
September 1939 to June 1940

Pre-War Organisation

There were three separate meteorological services in Egypt, viz :

(*a*) *Air Ministry Meteorological Service* was primarily responsible for meeting the needs of the Royal Navy, the Army and the Royal Air Force. It also provided meteorological facilities for civil aviation services operating in or through Egypt. There was a H.Q. forecast centre at Heliopolis, and subsidiary units at Heliopolis, Ismailia, Aboukir, Ramleh (Palestine) and Amman (Transjordan). A forecast unit was set up at Alexandria in September 1939, primarily to provide facilities for the Royal Navy; from 1 January 1940, it undertook all meteorological commitments for Imperial Airways.

Local collectives were broadcast by W/T from R.A.F. stations Ismailia and/or Heliopolis six times daily and a re-broadcast was made daily of Iraq collectives. A collective broadcast of morning reports from S.E. Europe, the Near East and Egypt and of upper winds and ships' reports was made once daily and area forecasts were broadcast twice daily.

(*b*) *Egyptian Meteorological Service, Physical Department, Cairo,* maintained a network of reporting stations in Egypt, manned almost wholly by part-time observers, making routine observations twice or thrice daily. It was concerned mainly with the needs of agriculture, irrigation, climatology and local government departments. Collective broadcasts of reports from Egypt, Cyprus and Palestine were made from Abu Saabal (Cairo).

(*c*) *Egyptian Civil Aviation Department Meteorological Service* was in its early stages of development. Three Egyptian meteorologists, trained at London University, were attached to the Air Ministry meteorological office at Heliopolis in the autumn of 1938 for practical training in forecasting and in the organisation of a meteorological service. Reporting stations for this service were set up at Almaza Airport (Cairo) and Dekheila Airport (Alexandria). From November 1939, the Egyptian officers undertook independent forecasting duties at Heliopolis and aditional reporting stations were set up at Mersa Matruh, Port Said, Minia and Sollum airfields.

In Palestine, the Palestine Meteorological Service had become responsible on 1 January 1939 for providing all meteorological facilities except those for R.A.F. units at Ramleh and at Amman (Transjordan) which were provided by the Air Ministry Meteorological Service, Middle East. The Palestine Meteorological Service had its H.Q. at Lydda Airport, and an excellent network of reporting stations was maintained although no collective W/T broadcasts had been inaugurated.

The meteorological service in Syria and the Lebanon was controlled by French officials. About 20 regular reporting stations were maintained and collective broadcasts were made by W/T from Beirut, the H.Q. of the service. Broadcasts for shipping were made several times daily.

There was no fully developed meteorological service in Cyprus, but there were several synoptic reporting stations and a large number of climatological and rainfall stations manned by part-time observers under the control of the Public Works Department, Cyprus.

In Iraq, a Meteorological Service, directed by an officer seconded from the Air Ministry Meteorological Office, controlled all meteorological stations in Iraq except those at R.A.F. stations at Habbaniya and Shaibah which were manned by Meteorological Office staff. Meteorological facilities for civil aviation at the airports of Baghdad and Basra were provided by the Iraqi Meteorological Service, but Imperial Airways flying boats, which landed on Lake Habbaniya obtained meteorological information from the Air Ministry Meteorological Service at Habbaniya. R.A.F. Habbaniya broadcast area forecasts for the R.A.F. twice daily.

At Aden, before the war, a meteorological reporting station was maintained by Indian staff under the control of the Director General of Observatories, India, but on 22 September 1939, an Air Ministry meteorological station was opened to meet the needs of the three fighting services.

In the Sudan, a meteorological service had been developed before the war, and a network of reporting stations had been set up. Apart from the Government Meteorologist and several British forecasters at Khartoum, the meteorological staff were Sudanese. Collective broadcasts of synoptic reports were issued by W/T from Khartoum.

There were well developed meteorological organisations in Italy and the Italian colonies before the war. Tripoli issued collective broadcasts for stations in Tripolitania and Benghazi for stations in Cyrenaica. Shipping reports were issued thrice daily by Benghazi and forecasts five times daily by Tripoli. In Italian East Africa, daily collective broadcasts of reports from stations in Eritrea, Somalia and Abyssinia were issued by Asmara, Mogadishu, Addis Ababa and Dire Daua; shipping messages were broadcast twice daily by Massawa, Mogadishu and Alula.

There was no national meteorological service in Iran. The India Meteorological Department maintained a number of meteorological reporting stations there, but telegraphic delays were frequent and sometimes the reports were not available for one or two days; a few reports were included in broadcasts from India.

Introduction of War Organisation

Instructions for sending and receiving meteorological messages in war were issued to meteorological staff at Heliopolis, Ismailia, Aboukir, Ramleh and Amman on 27 August 1939, and appropriate instructions regarding the meteorological procedure to be brought into effect at Heliopolis were issued to meteorological staff at all R.A.F. units. It was arranged for forecasts to be issued to H.Q. M.E. Operations Room, H.Q. Egypt Group, H.Q. R.A.F. Palestine and Transjordan, H.Q. British Troops in Egypt, and all other formations concerned.

A continuous 24-hour forecast service was introduced at Heliopolis on 28 August 1939 and, in accordance with Air Ministry instructions, the meteorological war organisation was brought into operation in Middle East on 2 September 1939. The routine reports from Aboukir and Ismailia were sent by telephone to Heliopolis, but those from Ramleh and Amman had to be sent by W/T encoded in CD 124 as land-line transmissions proved impracticable. The collective broadcasts were issued in C.M.C. C.D.32(2) from Ismailia and instructions were issued that all Confidential Meteorological offices in the Middle East area were to be used by Meteorological Office staff only.

The pre-war W/T broadcasts of forecasts, which had been temporarily stopped, were resumed on 27 September 1939. As adverse weather conditions did not usually last long and as the need for speed outweighed all other considerations, it was agreed that warning and improvement messages should be sent briefly in plain language by W/T. Other non-routine reports, if sent by W/T, were to be encoded in R.A.F. cypher to avoid compromising aircraft movements. Normal procedure was adopted for the supply of meteorological information for civil aviation, but no meteorological information was allowed to be supplied for stations, routes or areas west of Malta.

The Director, Meteorological Service, Physical Department, Cairo, was advised to continue the Egyptian meteorological broadcasts from Abu Saabal until he was told that the broadcasts should cease.

In October 1939, the Superintendent of the meteorological office, Heliopolis, visited Air Ministry where discussions were held on Middle East meteorological requirements with special reference to staff problems and on a proposal by H.Q. R.A.F. M.E. to amalgamate the Air Ministry meteorological service in Egypt and the Egyptian Civil Aviation meteorological service. It was agreed to accept this proposal in principle so long as amalgamation was necessary to maintain a meteorological war organisation in Egypt. In order to safeguard Air Ministry interests, certain stipulations were made regarding security and the duties and responsibilities of the Superintendent, Meteorological Office, Heliopolis.

Work for the British Forces and Civil Aviation

The outbreak of war caused a considerable increase in the work of the Air Ministry Meteorological Service, Middle East. Many requests were made for climatological data by the Intelligence Staffs of the Royal Navy, the Army and the Royal Air Force, particularly in respect of the Middle East area.

Meteorological staff were posted to Airways House, Alexandria, in early September 1939, to meet the requirements of the Royal Navy and of Imperial Airways; adequate communications facilities were provided. In addition to meeting the needs of the Royal Navy at Alexandria, arrangements were made for the supply of requested forecasts of gale warnings for the coast from Port Said to Haifa to the Naval Officer-in-Charge, Haifa. Arrangements were also made with the Fleet Navigating Officer in May 1940 for two R.N.V.R. Meteorological Officers to assist at the Meteorological Office, Alexandria. Weather charts were prepared and issued twice daily to the flagships of the British and French Navies, and 24-hour forecasts were supplied for the eastern Mediterranean. From May 1940, the Meteorological Office, Alexandria, provided all meteorological facilities for No. 201 Group, R.A.F. (Flying Boats).

Arrangements were made with British and Egyptian Artillery Staff Officers for the supply of additional Meteor reports to units at Cairo, Suez, Port Said, Fortress H.Q. Alexandria and Matruh. In fact, there was a general increase in the number of Meteor reports issued to Artillery and Anti-aircraft units. Frequent forecasts were supplied for Army exercises in the Western Desert.

In view of the importance of routine daily observations of upper air temperatures for the computation of ballistic temperatures for Naval and Army Services, efforts were made to inaugurate meteorological (THUM) flight by units of the R.A.F. or R.E.A.F. (Royal Egyptian Air Force) but the necessary aircraft could seldom be made available. However, THUM flights were made to 20,000 feet at Heliopolis during the Coast Defence and Air Defence of Egypt Exercises which were held in the Western Desert, the Delta and Canal areas in December 1939 and in May 1940.

Assistance was rendered in the establishment and maintenance of Egyptian Civil Aviation Department meteorological stations, and forecasts for the Baharia and Suez Canal areas were supplied twice daily to the Royal Egyptian Air Force Squadrons.

The Air Officer Commanding-in-Chief, H.Q. R.A.F. M.E., decided that the supply of meteorological information including the communication of meteorological information on the aircraft W/T wave band to all civil aviation services, except German, should continue as in peace-time. To avoid any risk of compromising codes, all routine weather and upper wind reports passed to Almaza airport contained the instruction 'These reports are for local use only and are not to be broadcast by W/T.' Normal meteorological facilities were provided for Imperial Airways, Misra Airworks, Air France, KLM and Ala Littoria.

The Superintendent visited the British Embassy in April 1940 for discussions on the meteorological organisation in Cyprus and the provision of meteorological facilities for civil aviation services.

Amalgamation of the Air Ministry and Egyptian Civil Aviation Department Meteorological Services[1]

The A.O.C.-in-C., H.Q., R.A.F., M.E., made proposals for a combined Air Ministry and Egyptian Civil Aviation Department Meteorological Service in War to His Excellency the Minister of National Defence, Egypt, and the Superintendent, M.E. Meteorological Service, prepared a war organisation for the combined meteorological services to serve as a basis for discussion at a conference at the Egyptian Civil Aviation Department on 10 September 1939. The scheme involved a Headquarters and Central Forecast section at Heliopolis, a subsidiary forecast centre at Alexandria, meteorological offices (rendering full synoptic reports and Meteor reports for Artillery and Anti-aircraft units) at Matruh, Aboukir, Ismailia and Baharia and the posting of forecasters to Matruh. In September 1939, consequent upon these proposals, an Egyptian meteorological officer was posted to Matruh, where routine Meteor reports were inaugurated, and also to Alexandria.

During December, the amalgamation of the Air Ministry and Egyptian Civil Aviation Department Meteorological Services and the formation of mobile meteorological units was further discussed at H.Q., R.A.F., M.E., at the

[1] A.M. Files S.36435 and S.69395.

Egyptian Ministry of Defence and at Heliopolis, while details of staff requirements on amalgamation were supplied to Air Ministry. Early in 1940, the scheme, including a proposal to transfer the meteorological H.Q. and main forecast centre from Heliopolis to Almaza airport, was approved by Air Ministry, and the H.Q. and forecast section moved to Almaza on 26 May 1940. The forecast section was maintained jointly by British and Egyptian staff under the control of the Superintendent, Air Ministry Meteorological Service, Middle East. It became the Central Forecasting Section for the Middle East and remained so until the end of the war.

Plans to Meet a Possible Extension of Hostilities

On the instruction of the A.O.C.-in-C., H.Q., R.A.F., M.E., a meteorological organisation for a proposed Expeditionary Force was drawn up. A copy was sent to Air Ministry on 14 February 1940 with a request for the necessary staff and three complete sets of meteorological equipment and stores. The first reinforcements of mobilised meteorological personnel arrived from United Kingdom on 25 April 1940. Arrangements were made for their training and study of Middle East weather conditions at the Meteorological office, Heliopolis.

Western Desert, 1940–1941

Developments in June 1940

Full meteorological war organisation was re-introduced in the Middle East area on 10 June 1940 and a continuous forecast service by British officers was started at Almaza from that night.[1] It was arranged that all Egyptian Civil Aviation Department meteorological stations should send their reports by land-line and not transmit any meteorological information by W/T. Routine collective issues were encyphered in C.D.32(5) by British staff at Almaza and passed by teleprinter from H.Q., R.A.F., M.E., for broadcast by W/T. The international collective broadcasts from Ismailia ceased on 11 June, while the forecasts were sent by land-line to H.Q., R.A.F., M.E., Heliopolis, Ismailia, Aboukir and Helwan, and by W/T, encoded in R.A.F. cypher, to Palestine and Transjordan.

Close co-operation was maintained with the Director of the Iraqi Meteorological Service and with the Government Meteorologist, Sudan. Iraq and Sudan collective reports, encyphered in Confidential Meteorological Cypher (C.M.C.), were received by W/T from Habbaniya and Khartoum respectively. The Iraq reports were re-broadcast from Ismailia and a limited number of reports from Egyptian and Sudanese stations also included in broadcasts from Ismailia.

Arrangements were made for meteorological reports from Nicosia (Cyprus) to be sent by cable instead of by W/T and for broadcasts of Egyptian collective reports from Abu Saabal (Cairo) to cease. Meteorological reports from Suda Bay and Mirabella (Crete) ceased on the evacuation of British Overseas Airways staff.

From 26 September 1941, all meteorological broadcasts were sent from Helmieh R.A.F. W/T station (near Almaza, Cairo) instead of from Ismailia and Heliopolis.

[1] A.M. File S.60464.

No Italian or Libyan reports were received from 10 June 1940, but in July 1940 it was arranged to receive reports from individual stations in Libya and the Dodecanese and these were decyphered by meteorological staff at Almaza. Syria collective meteorological broadcasts from Beirut ceased on 11 June but were resumed in normal meteorological code from 30 June to 9 October. No reports were received from French North African stations but, later, reports from some of the stations were received via Malta. Reports from Greece were received irregularly and arrangements were made for broadcasts of collective Greek reports, encyphered in C.M.C., to be made by R.A.F. W/T from 2 November 1940, until the evacuation of British military forces from Greece.

Meteorological Facilities for the Services

War requirements necessitated considerable increases in the supply of information to the Services. In addition to operational forecasts for the Royal Navy, the Army and the Royal Air Force (including Meteor reports to Artillery and Anti-Aircraft Units, forecasts for Balloon Barrage units and technical meteorological data and advice for specialised branches such as Chemical Warfare) climatological data, upper wind frequencies and meteorological appreciations were prepared for all actual and potential war areas in the Middle East and for reinforcement air routes between United Kingdom and the Middle East and between West Africa and the Middle East.

Close liaison was maintained with the C.-in-C., Mediterranean, at whose request the Meteorological Office, Alexandria, supplied Fleet synoptics and forecasts, encyphered in C.M.C., until 9 February 1941, when the commitments were undertaken by Malta.

Arrangements were made to issue weather forecasts, which were encyphered by Army personnel before broadcast by W/T, to units in the Western Desert. The provision of meteorological sections with Artillery Units was arranged with the G.H.Q., Cairo.

When the 4th Survey Field Regiment R.A., arrived in Middle East it was provided with a meteorological sound ranging unit and replacement equipment and consumable stores were supplied to this unit until it was detached for duty with an Indian Division in the Keren area during the Abyssinian campaign. This unit returned from Keren in April 1941, and, after refit, left for Tobruk. During its detachment to the Indian Division, the Officer Commanding 4th Survey Regiment requested another unit in its place but as no meteorological staff were available, 4th Survey Regiment Army personnel were trained in pilot balloon observations and computations and in the preparation of Meteor reports.

In May 1941, it was arranged to provide a mobile meteorological unit to operate with the Artillery in Palestine. Later, similar units were provided for the 2nd S.A. Artillery Division at Alamein, for Tobruk, for Advanced H.Q. XIII Corps, for H.Q. New Zealand Division, Eighth Army, and for the Levant, but the necessary transport and ancillary services were difficult to obtain. It was also arranged for shell bursts to be made at 20,000 and 30,000 feet by Artillery Units for the rapid determination of winds at those levels.

Lack of meteorological staff made difficult the development of an adequate meteorological organisation for the R.A.F. but, at the beginning of July 1940, a forecast unit was established at H.Q. No. 202 Group (Western Desert) at Maaten Bagush and the necessary transport to make the unit fully mobile was gradually obtained. A forecast unit was provided at H.Q. Heavy Bomber Wing, Shallufa, in January 1941 and a subsidiary meteorological office was set up at Mersa Matruh. As there were no satisfactory communications facilities at Matruh, it was arranged to provide a pack W/T set and wireless operators for sending meteorological reports to H.Q. No. 202 Group, Western Desert. One of the greatest difficulties was inadequate signals communications, resulting in great delays in sending weather reports, forecasts, etc., and the Chief Signals Officer was told of the signals facilities required for the meteorological organisation in the Command. The staff difficulties were slightly alleviated when in June 1941 the Air Ministry authorised the training and remustering to meteorologist of 50 airmen (except airmen in Group I trades). A number of airmen were chosen and sent for training to Heliopolis, Ismailia and Aboukir.

In December 1940, the Assistant Director for Overseas Services, Meteorological Office, accompanied by the Superintendent, Middle East Meteorological Service, visited H.Q., R.A.F., M.E.; G.H.Q., M.E.; various sub-formations and the Egyptian Ministry of Defence. Detailed meteorological establishments were prepared for each Command and operational area and provision was made for meteorological units for the Army but great delay occurred in authorising the establishments despite repeated signals from H.Q., R.A.F., M.E. to Air Ministry. In fact, it was not until December 1941 that new meteorological establishments were approved for Egypt, Western Desert, Palestine, Trans-Jordan, Cyprus, Syria, Persia and two O.T.U.s in East Africa. These establishments included 10 mobile units for Artillery.

In February 1941, the Superintendent undertook regular duties at H.Q., R.A.F., M.E., instead of at Almaza, visiting Almaza each morning and evening before proceeding to H.Q., R.A.F., M.E., in order to collect a copy of the latest weather map and to study weather developments so that up-to-date briefing and advice could be given to the C.-in-C., the A.O.C.-in-C., and Air Staff Officers.

In May 1941, the A.O.C.-in-C. signalled A.M.S.O. that it was essential to commission the Superintendent, Meteorological Services, Middle East, in order to secure effective control and co-ordination of R.A.F. and civil meteorological organisations throughout the Middle East Command. All civilian meteorological officers in Middle East were granted C.C. commissions in November 1941, and the Superintendent became Chief Meteorological Officer with the rank of Group Captain. In January 1942, Air Ministry stated that he was to control the meteorological services in Egypt, Western Desert, Iraq, Persia, Palestine, Transjordan, Aden, Syria and Cyprus as long as those areas were under the administrative control of H.Q., R.A.F., M.E.

Meteorological Units in Forward Areas

Before June 1940 most of the countries bordering the Mediterranean broadcast collective meteorological reports in the normal international meteorological codes, but on the entry of Italy into the war and the collapse of France, normal meteorological broadcasts ceased and Malta was the only station between Spain and Egypt from which reports were available. Thus the provision of meteorological facilities for the increasing needs of the Fighting Services was extremely difficult especially as the regions to the west and north, from which the main weather systems travelled, were almost entirely under enemy control; moreover, there was only a very meagre network of reporting stations in areas under allied control in the Middle East.

The first meteorological forecast unit to be established in a forward area was that at H.Q., No. 202 Group (Western Desert) at Maaten Bagush. Here synoptic and upper wind observations were made, encyphered and sent by W/T to the main forecast centre at Almaza. Weather forecasts were received from Almaza, amplified as necessary in the light of local experiences and in-flight reports received from aircrews, and were supplied to the A.O.C., Operations Staff and to Squadrons ; meteorological facilities were provided also for Army Commands in addition to Meteor reports for Artillery and Anti-aircraft Batteries and special reports for smoke screen operations ; whenever possible, upper air temperatures were obtained from R.A.F. aircraft.

Just before General Wavell's first offensive opened in December 1940, a mobile meteorological unit was formed and attached to the Royal Australian Artillery. It was equipped as a reporting and upper wind observing station, mainly for the provision of Meteor reports to artillery units, and of weather reports to its parent unit at H.Q., No. 202 Group, but it depended on Army signals communications and great delays occurred in the transmission of the weather reports. The unit moved with the Artillery to a position near Bardia in January 1941, and to a location south of Benghazi in February 1941.

The meteorological forecast unit with H.Q., No. 202 Group left Maaten Bagush on 8 January 1941 and moved to Sollum and to El Adem and then on to Barce by 7 March 1941, but the occupation of Agheila by the Germans at the end of March 1941, and their subsequent advance eastwards, forced the unit to retire from Barce on 3 April. It eventually arrived back at Maaten Bagush ; practically all the equipment was lost or destroyed. The mobile meteorological unit with the Australian Artillery was withdrawn to Tobruk, where it remained throughout the siege, making routine meteorological observations which were encyphered and sent by W/T to Almaza, and providing Meteor telegrams for the Field and A.A. batteries defending the fortress.

Lack of transport considerably hampered effective liaison with operational units. Frequent requests were made for a utility van for the forecasting unit at R.A.F., H.Q., Western Desert but it was not until August 1941 that one was supplied, thus enabling a meteorological officer to visit Advanced H.Q., No. 257 Wing and L G Z to brief Air Staff Officers and Bomber crews.

As a result of the experience gained in the first campaign in the Western Desert, three distinct types of meteorological units were developed, namely—

(*a*) a meteorological Forecast Unit, similar to a Type 1 office in the United Kingdom, and attached normally to an Air Headquarters or to a Group ;

(*b*) a mobile Meteorological Unit, attached normally to an Army Corps Headquarters, primarily for the provision of meteorological facilities for Army Units, including Meteor reports for artillery and anti-aircraft formations, and of synoptic and upper wind reports to the parent forecast unit.

(*c*) a reporting and Distributive Meteorological Unit, attached to an R.A.F., Unit, Staging Post or Operational Airfield.

It soon became clear, however, that all meteorological units in forward areas should be independent of Army or R.A.F. formations in that it was essential for mobility, the rapid exchange of vital meteorological information and the

briefing of aircrews. It was also clear that they should be provided with their own transport and communications, but the Air Ministry did not approve the provision of these essential ancillary services until late 1941.

Establishment of Meteorological Flights

From the outbreak of war repeated efforts had been made to obtain routine observations of upper air temperatures in different areas of the Middle East Command, but lack of aircraft made such regular observations impracticable. In April 1941, however, an establishment was approved for a Meteorological Flight at Heliopolis, consisting of Gladiator aircraft, and Thum flights were made twice daily at dawn and about midday. From 28 June 1941, a detachment of one aircraft from this Flight was posted to H.Q., R.A.F., Western Desert, where it made one ascent daily. These routine observations of upper air temperatures proved very valuable and further efforts were made to establish additional Meteorological Flights. Establishments were approved for Meteorological Flights at Khartoum and Ramleh in September 1941, and for one at Nairobi in November 1941. Subsequently, Meteorological Flights operated in Greece, Cyprus, Iraq, Libya, Aden and Madagascar.

Codes

The shortage of meteorological personnel made it difficult to cope with the ever increasing volume of cypher work and the Chief Signals Officer arranged for R.A.F. Cypher Officers to be posted to forecast units to undertake meteorological cypher duties.

Other Meteorological Services

Egyptian meteorological staff were withdrawn from Sollum on 13 June 1940 and from Matruh on 18 June 1940. As the Egyptian meteorological staff were unmobilised and could not operate in forward areas, arrangements were made for Egyptian Civil Aviation Department meteorological offices to be opened at Luxor and at El Arish.

Meteorological reporting stations were established at Riyadh and at Hail in Saudi Arabia by the Director of the Iraqi Meteorological Service in March 1941.

In September 1940 a meteorological officer was posted from the United Kingdom to organise a meteorological service in Cyprus. Discussions were held with all the authorities concerned including the Director of Public Works who controlled the climatological and rainfall stations in Cyprus. Some of the coast watchers were trained in meteorological observing, and gradually a small network of meteorological reporting stations was developed. Arrangements were made to provide R.A.F. signals personnel and equipment for receiving and transmitting meteorological collective messages. Subsequently a forecast unit was established at Nicosia.[1]

Early in 1940, the Superintendent, Meteorological Service, Middle East, had visited Palestine to discuss with the local authorities, particularly the Director of Civil Aviation, the provision of an effective meteorological organisation in Palestine. It was proposed that the Palestine meteorological service should be placed at the disposal of Air Ministry and that British personnel should be

[1] A.M. File S.55813.

posted to Lydda to supervise the service and to undertake all cypher duties and thus ensure that the forecast service functioned efficiently. The Air Ministry were, therefore, requested, to post British meteorological officers to Lydda to control the forecast service and use all confidential meteorological codes[1]. A meteorological officer was posted to Ramleh for duty at Lydda in October 1940, and in November the Senior Meteorological Officer, Iraq, was posted to Palestine to take charge of the Palestine Meteorological Service. Collective meteorological messages for Palestine were broadcast in C.M.C. from 1 January 1941.[2]

Abyssinian Campaign, early 1941 ; Co-operation with the South African Meteorological Service

Before East Africa had become an operational area, when Italy declared war in June 1940, manœuvres had taken place in the Isiolo area in which a S. Rhodesian Air Force Squadron participated, and the Assistant Director of the British East Africa Meteorological Service (B.E.A.M.S.) was attached as a meteorologist. The militarisation of meteorological staff was not considered necessary at first but meteorological officers wore Kenya civil uniform when attached to a military unit.

The Deputy Director of the Meteorological Service, South African Air Force, Pretoria, was given details of the meteorological organisation in East Africa and of the facilities which would be available for mobile meteorological units which were to be sent to East Africa with the S.A.A.F. It was agreed that, as the staff of the British East Africa Meteorological Service was unmobilised, they should undertake all basic forecasting duties and that the S.A.A.F. meteorological units should undertake all field work and liaison with military formations. The first S.A.A.F. mobile meteorological unit arrived in Nairobi on 24 May 1940.

In view of their limited numbers, staff of the British East Africa Meteorological Service were assisted by senior officers of other Government in coding, plotting and supervisory duties from 18 June 1940 until August 1942. S.A.A.F. personnel helped in the forecast office and the senior S.A.A.F. meteorological officer was appointed to the combined Air Force Headquarters. A meteorological office was established on the Nairobi aerodrome ; arrangements were made to install telephone tie lines and other signals facilities, and all B.E.A.M.S. equipment and resources were made available to the S.A.A.F. Meteorological Services.

The meteorological service operated on a continuous 24-hour basis as from 11 June 1940, and full security measures were brought into force. Arrangements were made for the supply of information to and from mobile field units, codes were prepared, and meteorological equipment, including portable hydrogen generators, was issued, so that everything was ready for the advance of operational units. Forecasts were issued for long range photographic reconnaissance, and memoranda and maps on the climate of East Africa, magnetic declination, etc., were prepared.

Before the Abyssinian campaign opened, meteorological officers and airmen were posted from Middle East for duty in the Sudan. The meteorological unit which had been attached to the 4th Survey Regiment moved to the Sudan to operate with the 4th Indian Division, and arrived at Karen in February 1941, where it provided Meteor reports for artillery units.

[1] A.M. Files S.65658 and S.99839. [2] A.M. File S.87405.

As S.A.A.F. meteorological units advanced with Air Force and Artillery formations, communications were maintained for the supply of information resulting in close co-operation between forward units and base H.Q. All Italian broadcasts were monitored and meteorological messages were passed to the meteorological office at Nairobi. The first routine meteorological report was sent by a S.A.A.F. meteorological unit from Addis Ababa within 24 hours of the Italian reports ceasing after capitulation.

On the occupation of Italian territory, S.A.A.F. meteorological units tried to locate meteorological equipment and records. Serviceable meteorological equipment was taken over by the S.A.A.F. in replacement of B.E.A.M.S. equipment and all records were handed over to the B.E.A.M.S.

Arrangements were made in July 1941, for the Senior Meteorological Officer, Aden, to visit Addis Ababa to make recommendations for the reorganisation of the meteorological services in Abyssinia, Eritrea and Somaliland, and in mid-August 1941 he visited H.Q., R.A.F., M.E., for discussions on his proposals.

After the conclusion of the Abyssinian campaign some of the S.A.A.F. meteorological units moved to the Middle East, but for some time the S.A.A.F. service maintained meteorological facilities at military establishments in East Africa including those at Nakuru, Mombasa, Eastleigh, and Mogadishu. From December 1941, Air Ministry Meteorological Office staff gradually increased, and all S.A.A.F. meteorological personnel were withdrawn from East Africa by the end of 1942.

In May 1941, H.Q., R.A.F., M.E., received from Defence H.Q., Pretoria, proposals of the Deputy Director S.A.A.F. Meteorological Service for providing S.A.A.F. meteorological units for all South African Air Force formations leaving the East Africa Command for the Middle East. A Senior S.A.A.F. meteorological officer visited H.Q., R.A.F., M.E., in June 1941, to discuss these proposals. As a result recommendations were made for the posting of a S.A.A.F. meteorological officer as liaison officer at H.Q., R.A.F., M.E., the provision of S.A.A.F. meteorological units with S.A.A.F. Wings or Squadrons, the posting of S.A.A.F. meteorological officers to Almaza for short periods to study weather forecasting in the Middle East area and the supply of meteorological and signals equipment by the S.A.A.F. to each of its meteorological units. These recommendations were implemented during 1941 and very close and cordial relations were maintained with the S.A.A.F. meteorological service, who gave valuable aid in the provision of meteorological facilities.

Rebellion in Iraq, April 1941 ; Reorganisation of the Iraqi Meteorological Service[1]

In the early part of 1941 the Air Ministry Meteorological Service maintained a forecasting office at Habbaniya (staffed by three British forecasters, one British assistant and a number of Iraqi assistants) and an observing station at Shaibah (manned by Iraqi assistants) : two additional forecasters arrived in Iraq in March 1941, and Shaibah was re-opened as a subsidiary forecasting office.

The Iraqi Meteorological Service, maintained synoptic reporting stations throughout Iraq and forecasting offices at Baghdad and at Basra, the latter commanded by a British Officer seconded to the Port Directorate.

[1] A.M. Files S.87406 and S.69289.

Synoptic reports from Habbaniya, Shaibah and the Iraqi stations were encyphered in local cypher, a different one being used by each station; the reports were collected at Baghdad airport, while the Baghdad collective broadcast was issued in a separate Iraqi cypher, copies of which were supplied only to the British units concerned. Reports to aircraft in flight were issued in a special cypher, copies of which were held by Habbaniya, Shaibah, the Director of the Iraqi Meteorological Service and the Port Meteorologist, Basra.

Towards the end of April 1941, when relations with the Iraqi Government were strained, telephonic communications between Habbiniya and Baghdad were cut off on several occasions and at times the Iraqi authorities refused to allow coded meteorological messages to be telephoned between Habbaniya and Baghdad airport. On 30 April, the Iraqis ceased to broadcast meteorological information and the only Iraqi reports available to British forecasting officers were those from Habbaniya and Shaibah. The reports from Ismailia, Lydda, Habbaniya and Shaibah were therefore withheld from the Iraqi Meteorological Service.

On 2 May 1941, Iraqis surrounded and isolated the camp and airfield at Habbaniya. For the first few weeks in May, when the camp was subjected to shelling and bombing, the Iraqi meteorological assistants were confined to the civil cantonment and British staff undertook all routine observational duties. The British meteorological officers in Iraq were given honorary commissions in the R.A.F. and wore uniform, but, as these commissions did not cover service indemnification against war risks, urgent representations were made to Air Ministry for the British Officers to be given R.A.F.V.R. Commissions.

For a short time no meteorological W/T receptions were possible but they were resumed as soon as W/T operators became available. During the rebellion, the Port Meteorologist, Basra, continued to maintain a forecasting office at Basra; he could provide east-bound forecasts for B.O.A.C. Services but as he had no reports from Habbaniya or Lydda the west-bound forecasts were supplied to him from Shaibah.

Hostilities ceased on 31 May 1941. On the same day, contact was made with the Director of the Iraqi Meteorological Service who had been marooned in the British Embassy, Baghdad, and Air Ministry were informed that he had destroyed all codes and secret documents on 30 April before there was any possibility of Iraqis obtaining possession of them. As the Indian meteorological codes had been in the possession of the Iraqi service, A.H.Q., India, issued new code books towards the end of May 1941.

On 7 June 1941, the Director of the Iraqi Meteorological Service and the Senior Meteorological Officer, Iraq, discussed with the A.O.C., Iraq, the policy to be adopted for the reorganisation of the meteorological services in Iraq and for the collaboration of the British and Iraqi meteorological services. The Air Ministry decided that an organisation embracing the whole of Iraq should be established which would meet efficiently military and other requirements, and, at the same time, ensure maximum security. Iraqi meteorological outstations would continue to be manned by Iraqi assistants, who would send the observations encyphered to Baghdad; a different cypher would be provided for each outstation which would hold that cypher only; the forecast centre at Habbaniya would be the only meteorological office in Iraq holding copies of all the outstations cyphers. As the encyphered meteorological reports were received at Baghdad they would be sent by W/T to Habbaniya who would

decypher them and broadcast them by W/T, re-encyphered in a British Cypher, for the benefit of Shaibah and other British meteorological offices concerned. The Iraqi meteorological offices would have no Iraqi reports and Baghdad and Basra would cease to maintain their forecasting stations, all forecasts being provided by Habbaniya and Shaibah, except forecasts for east-bound B.O.A.C. aircraft which would continue to be issued by the Port Meteorologist, Basra.[1]

All the Iraqi outstations were in operation again in June, with the exception of Rutbah and Haditha; the former was re-opened on 15 August and the latter on 24 August 1941

Greece and Crete 1940–1941

When Italy invaded Greece in October 1940, the normal Greek collective meteorological broadcasts from Athens ceased, causing another serious blank in the weather map of the Mediterranean area. A meteorological officer was posted to Athens at the beginning of November 1940, to investigate and report on the meteorological requirements of the British military forces in Greece.

From an R.A.F. point of view the great danger in the operational area was low cloud, so it was arranged with the Greek Meteorological Service for weather reports to be made by meteorological observers in the north-western area of Greece and by staff manning about thirty observation posts of the Air Defence Centre. These reports were sent rapidly by telephone to the meteorological officer at A.H.Q., Greece, Athens. In addition, it was arranged for routine Greek synoptic reports to be passed by the Greek Meteorological Service to the British Meteorological officer, encyphered by him in British confidential meteorological code, and broadcast by R.A.F. W/T. R.A.F. signals personnel and equipment were provided for the reception of collective meteorological broadcasts.

Full meteorological facilities were provided at A.H.Q., Greece, and for R.A.F. Squadrons at Eleusis and Mendidi, and, with excellent co-operation from the Greek authorities, an adequate network of reporting stations was developed, ensuring hourly weather reports along parts of the routes over which our aircraft operated. Weather conditions were often extremely difficult and on many nights the Wellington aircraft were unable to negotiate the Gulf of Corinth or to fly over the mountains. Blenheim aircraft often flew through weather as hazardous as any found in Europe while at other times, when fighter cover was not available, they were compelled to turn back at the frontier owing to absence of any cloud cover over the whole of Albania.

As additional meteorological personnel became available in the Middle East the meteorological forecast unit at A.H.Q., Greece, was strengthened and by March 1941 was operating on a continuous 24-hour basis. While on patrol duties the Sunderland flying boats made weather observations which provided invaluable information for meteorological briefing and added considerably to the knowledge of weather conditions over the Aegean, Adriatic and Tyrrhenean Seas.

In December 1940, a meteorological officer visited Crete to investigate the requirements of Naval, Army and Air Force units located there. Arrangements were made to form a subsidiary forecast unit at Heraklion in February 1941 and to provide R.A.F. signals personnel and equipment for sending and receiving

[1] A.M. File S.87406.

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meteorological collective messages. Some meteorological facilities were made available at Canea and Maleme, and observations of upper air temperatures were made in the Suda Bay area.

When the British Expeditionary force reached Greece in March 1941 a mobile meteorological unit was provided for the Artillery. This arrived in Athens on 19 March, complete with equipment and a 3-ton lorry, and was attached to H.Q., Medium Artillery 1st Australian Corps. The unit moved from Athens to Servia on 7 April and operated with the Artillery in engagements with the Germans as far north as Florina, being subjected to many low dive bombing attacks. With the arrival of considerable German forces in Greece the military situation became critical and the unit was compelled to fall back with the Australians, first to Larissa and then to the Athens area. Greece was evacuated at the end of April 1941 and all meteorological personnel were withdrawn safely to Crete or Egypt, but all meteorological instruments and equipment were lost.

On the evacuation of Greece the meteorological services in Crete were strengthened. In mid-May 1941, the forecasting unit was transferred from Heraklion to Canea to ensure better W/T facilities and closer co-operation with the naval meteorological personnel, but owing to the German invasion the unit had to be withdrawn before the end of May ; the majority of the meteorological personnel being evacuated safely to Egypt.

Entry into Syria, June 1941 ; Co-operation with the Free French Meteorological Service[1]

On 6 June 1941, a mobile meteorological unit left Egypt for attachment to the 7th Australian Divisional Artillery, complete with meteorological equipment and a 3-ton lorry provided by H.Q., R.A.F., M.E., Routine synoptic observations were made, whenever movements permitted, and signalled to Ramleh. Meteor reports were supplied as requested by the Artillery during the period of hostilities. Subsequently a meteorological officer was attached to R.A.F., Ramleh, for special duties in Syria.

Proposals for an Air Ministry meteorological organisation in Syria were signalled to London in July, but on 4 August 1941 a conference was held at Headquarters, Middle East, with Free French representatives, and it was decided that the Free French would be responsible for the regional meteorological organisation in Syria and the Lebanon. The Chief Meteorological Officer, Middle East, was instructed to give every help to the Free French in organising an efficient meteorological service and in providing meteorological facilities for British military forces, such facilities to include a subsidiary forecasting unit at Beirut and reporting units at airfields manned by the Royal Air Force ; signals facilities for receiving and sending meteorological reports would be required at Beirut but Syrian collective meteorological messages would be broadcast with the existing FAFL W/T transmitter at Beirut ; at stations or aerodromes manned by R.A.F. Squadrons, signals facilities would be required for the exchange of meteorological information between Beirut and each station or aerodrome.

[1] A.M. Files S.75382 and S.72858.

A meteorological officer and some airmen were posted to Beirut to assist the F.A.F.L., to organise a meteorological forecasting unit at Beirut for the provision of meteorological facilities for British military services, and to advise the F.A.F.L. on the development of a network of meteorological reporting stations and on the training of locally engaged staff as meteorological observers. Arrangements were made to provide Royal Air Force signals personnel and equipment at Beirut and broadcast of Syrian collective meteorological reports. From 27 September broadcasts were made six times daily, and increased later to eight times daily.

Apart from two days spent at Beirut for the calibration of anti-aircraft guns, the mobile meteorological unit was stationed in the vicinity of Baalbek in August 1941 and supplied Meteor reports to British and Australian artillery units and to the Sound Ranging Troop of the Australian Survey Regiment. From 23 September 1941 the unit assisted the meteorological forecasting unit at Beirut except when required for calibration trials.

The Air Ministry approved, in November, the daily issue of weather information in cypher to F.A.F.L. pilots and to the Senior F.A.F.L. Meteorological Officer at Beirut for re-cyphering before transmission to F.A.F.L. meteorological stations in Syria.

Proposals to establish British meteorological units in Syria were approved in December 1941, and comprised a meteorological forecasting unit at Beirut, three reporting stations (at Hassetche, Aleppo and Deir-ez-zor) and four mobile mateorological units.

The closest co-operation and liaison was maintained with the F.A.F.L. meteorological service which gradually developed an efficient network of meteorological reporting stations. It also maintained a headquarters centre, W/T station and a forecasting office in Beirut although its work was mainly of a climatological nature. All forecasting facilities for British military forces and for civil aviation, both British and Allied, were provided by the British forecast unit which was located at first in the town but subsequently at the airfield in Beirut.

Entry into Iran, September 1941 ; Co-operation with the U.S.S.R.[1]

During August 1941 lectures on general weather conditions over Iran and Transcaucasia were given to the Royal Air Force Squadrons based at Habbaniya, and instructions in the preparation of abbreviated weather reports was given to No. 16 Wireless Observer Unit with a view to obtaining reports of this nature from observation posts. From 25 August Royal Air Force Squadrons were briefed for operational flights over Iran and these meteorological briefings continued throughout the Iranian campaign.

At that time there was no national meteorological service in Iran but the Director-General of Observatories, India Meteorological Department, had established meteorological observing stations at British consulates in Iran and reports were normally cabled twice daily to India. Air Headquarters, Iraq, requested Air Headquarters, India, that the India Meteorological Department should arrange for a collective broadcast to be made from an Iranian station. This proved impracticable and it was arranged that direct telegrams should be sent from selected Iranian stations to the Meteorological Office,

[1] A.M. File S.74960.

Habbaniya. In addition, arrangements were made by the Senior Meteorological Officer, Iraq, with the Anglo-Iranian Oil Company for weather reports to be supplied daily from Abadan, Kermanshah and Majd-i-Sulaimn to Habbaniya via Abadan and Shaibah.

A military mission leaving Iraq for Russia was asked to arrange, if possible, for the Russians to broadcast a collective message from Tiflis, including meteorological reports from Transcaucasia and the eastern Black Sea coast. The Russians would not do this in their cypher but suggested that they would supply weather information for special flights on request.[1]

A request for the provision of a meteorological forecasting unit for Teheran was made to Air Ministry in October 1941, and at the beginning of November the Senior Meteorological Officer, Iraq, went to Teheran to arrange for the provision of meteorological facilities for flights of service and B.O.A.C. aircraft to Iran. It was decided to establish a meteorological reporting station on the aerodrome at Teheran immediately and in mid-November an airman was posted with equipment for synoptic and upper wind reports. Routine observations began on 18 November and approval was given to recruit, train and re-muster to meteorologist four airmen for duty at Teheran and four locally engaged staff for duty at Kazvin and Hamadan. In December a subsidiary forecast unit at Teheran was sanctioned and an officer was posted there on 17 December. The forecast unit was transferred to Qale Morgheh aerodrome (Teheran) on 20 January 1942.

The Director General of Observatories, India Meteorological Department (I.M.D.), was informed of the development of the Air Ministry meteorological service in Iran and arrangements were made for the synoptic reports from some of the I.M.D. stations in Iran to be telegraphed to Teheran. Great difficulties and delays were experienced owing to the very poor signals communications facilities in Iran.

A meteorological reporting station was opened at Hamadan on 5 February and one at Sultanabad on 27 March 1942. Abbreviated weather reports were also received thrice daily by Teheran from Railway Construction Company staff at Andimeshk from 23 April and at Durud from 18 May.

The daily exchange of collective synoptic reports, encyphered in one-time meteorological pad cypher, between Habbaniya (Iraq) and Tiflis began on 20 January 1942 but ceased on the departure of the Mission from Tiflis in February 1942, as the Russians at Tiflis were unable to arrange for W/T meteorological transmissions and were not authorised to take over the cyphers needed for decyphering the Habbaniya broadcasts.[2]

There was good liaison with the Russian meteorological office staff at Qale Morgheh and a considerable amount of meteorological information was exchanged between the Russian and British meteorological forecast units. The Russians had recently started forecasting for all their aircraft departing from Qale Morgheh aerodrome, although forecasts were often issued by British staff to Russian pilots southwards from Teheran.

Repeated efforts were made to re-commence the collective meteorological broadcast exchanges between Tiflis and Habbaniya but it was not until August 1942 that satisfactory broadcasts were effected. Proposed times and frequencies of the broadcasts from Habbaniya for reception in Russia were

[1] A.M. File S.69297.

[2] A.M. Files S.77453 and S.69297.

approved in July 1942 and four transmissions daily were begun on 25 July. The messages consisted of a selection of synoptic and upper wind reports from a number of stations in Iraq, Iran, Syria and Cyprus.

A meteorological reporting station began operating at Qum on 31 August and from 7 September collective broadcasts, which included reports from Russian stations in Northern Iran, were made thrice daily by the Meteorological Office, Teheran. In addition upper air temperature observations were made at Teheran from 19 November 1942.[1]

In March 1943, owing to the withdrawal of the R.A.F. from Qale Morgheh aerodrome, the meteorological forecast unit was transferred to Mehrabad aerodrome, about 4 miles west of Teheran and 3½ miles north-west of Qale Morgheh. For a time stations were maintained at Durud, Abadan, Quam, Hamadan, Sultanabad and Kermanshah. By September 1945 the British meteorological service was reduced to reporting stations maintained at the British Embassies or consulates at Teheran, Ispahan, Kermanshah and Hamadan.

Western Desert (November 1941–May 1943)

‘ Crusader ’ Operation

In the summer and autumn of 1941 the meteorological services in Egypt and the Western Desert were expanded in preparation for operation ‘ Crusader ’. This expansion was made possible by the withdrawal of personnel from Greece and Crete and by the virtual end of the East African campaign in May and the consequent posting of South African Air Force meteorological personnel from East Africa to the middle East.

In June 1941, a meteorological unit was provided for the Wellington Bomber Wing at Shallufa in the Canal Zone, Egypt, and in September a mobile meteorological unit was provided for Advanced H.Q. XIII Corps in the Sidi Barrani area, while a detachment of the Heliopolis meteorological flight was established with the A.H.Q., Western Desert meteorological forecast unit at Maaten Bagush.

Anticipating an advance westwards, arrangements were made at the beginning of November 1941 for the forecast unit at Shallufa to move to Advanced H.Q. No. 205 Group and to assume responsibility for providing all meteorological facilities in the Western Desert when the forecast unit at A.H.Q., Western Desert moved into Libya. When the offensive began on 18 November 1941 the meteorological units moved forward with the Army and Royal Air Force. In the main battle area frequent Meteor reports were supplied to artillery units for the bombardment of enemy strong points, and on 24 November a S.A.A.F. meteorological unit began to supply regular weather reports from Giarabub at the southern end of the front. The mobile meteorological unit with H.Q., XIII Corps, was the first R.A.F. unit to enter Tobruk after the siege was raised on 9 December 1941. This unit left Tobruk on 19 December and moved successively to Acroma, Mechili and Msus, eventually reaching Antelat by the New Year. During this advance engagements with the enemy were short and Meteor reports were not required, but at the beginning of January 1942 the unit was attached to the 1st Field Regiment R.A. and

[1] A.M. File S.87406

supplied hourly Meteor reports for the bombardment of Jedabya airfield. Later in the month it undertook similar duties for the bombardment of isolated pockets of resistance in Sollum and Halfaya.

The forecast unit with A.H.Q., Western Desert, left Maaten Bagush on 29 December 1941 and a full forecasting service was established at El Adem on 4 January 1942. While the unit was in transit forecasts for forward operational formations were issued by Advanced H.Q. No. 205 Group or by the Central Forecast Section, Almaza. An Advanced A.H.Q., Western Desert was formed but, as it was deemed essential to limit its numbers, a liaison meteorologist only was provided. Weather reports were received from this Advanced A.H.Q., Western Desert at Tmimi from 5 January and from Gazala from 30 January 1942. As the advance continued meteorological reporting units were established at Sidi Barrani, Sollum, Tobruk, Derna and Berka (Benghazi).

A very strong German counter-offensive began on 21 January 1942 and the forward reporting stations had to be withdrawn. On 2 February 1942 the forecast unit at A.H.Q., Western Desert was instructed to retire from El Adem to its old site at Maaten Bagush. During February the meteorologist at Advanced A.H.Q., Western Desert received forecasts from Advanced H.Q. No. 205 Group until the forecast unit with A.H.Q., Western Desert was in operation. The forecasts were issued to Operations Staff, Air Support Wing, H.Q., Eighth Army, Advanced H.Q., No. 235 Wing, No. 234 Wing Detachment and other sub-formations and neighbouring units.

During the operation, No. 1 Mobile Met. Unit with the Survey Regiment operated at Tobruk, Bardia, and Halfaya Pass before returning to the Cairo area, while No. 2 Mobile Met. Unit operated also at Jedabya and at Tmimi. The Official Report on the first phase of these operations at the end of 1941 mentioned the high value of the Meteor reports supplied to artillery units.

Re-organisation after the 'Crusader' Operation

As the meteorological units at A.H.Q., Western Desert (Maaten Bagush) and H.Q. No. 205 Group (Daba area) were comparatively close, a tour of the advanced landing grounds in the Gambut and Sidi Barrani areas was made in March 1942 in order to find a more suitable location for the A.H.Q., Western Desert forecast unit, and arrangements were made for this unit to move to Sidi Barrani on 14 April 1942. This new location facilitated the rapid communication of forecasts to forward units, permitted the meteorological briefing of Bomber crews, and ensured the prompt provision of pilots' weather reports on their return from reconnaissance and operational flights. The forecast unit from H.Q. No. 205 Group, was attached to No. 231 Wing and provided meteorological facilities for desert units east of, and including, Matruh.

No. 3 Mobile Met. Unit was formed and equipped and left Heliopolis on 23 April for attachment to 12th Heavy A.A. Brigade (in the Gambut area) which was engaged in the anti-aircraft defence of advanced Fighter airfields. Signals communications between mobile meteorological units and their parent forecast unit were still difficult and in April 1942 the Chief Signals Officer was asked to provide one wireless and a W/T pack set for each mobile meteorological unit so that reports and forecasts could be received promptly and the information distributed to neighbouring Army and R.A.F. units, and also for the rapid transmission of weather reports to the parent forecast unit.

During the early part of 1942 the work of the Central Forecast Section at Almaza increased considerably. Direct flights from Egypt to the United Kingdom became more and more frequent and eventually daily briefings were given to pilots and navigators for these flights. The route from Middle East to Teheran and Moscow began to be used regularly and Liberator aircraft arrived in the Command and made operational sorties over a wide area. Activity at LG224 (Cairo West), the terminal in Egypt for flights from the United Kingdom increased rapidly and later a forecast unit was established there. Developments occurred also at Alexandria where the forecast unit became mainly a naval co-operation unit and eventually was attached permanently to H.Q., No. 201 Group.

The numbers of Meteorological Flights increased and routine Thum observations were made at Heliopolis, A.H.Q., Western Desert, Khartoum, Summit, Ramleh, and Nicosia.

In February 1942 a new meteorological establishment for Egypt, Western Desert, Levant, Iraq, Iran, Operational Training Units in East Africa, Somaliland, Aden, Eritrea and Sudan was approved. It comprised 84 officers and 309 assistants but in June 1942 the strengths were still less than half of the establishments.

German Offensive, June 1942

The German offensive in the Western Desert began in June 1942 and made rapid progress. Meteorological units had to retire eastwards. On 17 June the liaison meteorologist at Advanced Air Headquarters, Western Desert was instructed to return to the forecast unit, A.H.Q., Western Desert, which at that time was with H.Q. No. 235 Wing at Sidi Barrani. Shortly afterwards withdrawal from Sidi Barrani became imperative and the unit was instructed to take over the commitments of the forecast unit with H.Q. No. 231 Wing which then withdrew to the Canal Zone on 25 June. Further withdrawal became essential and on 27 June the forecast unit proceeded first to Amriya, then to Burg El Arab and later to a position near Abu Sueir. The meteorological unit at Mersa Matruh was compelled to withdraw on 23 June and all personnel and equipment were evacuated to the Cairo area.

The forecast unit of H.Q. No. 205 Group (attached to H.Q. No. 231 Wing) was withdrawn from Qataifiya on 25 June and moved first to LG224, then to Ismailia, and on 1 July to Rear H.Q. No. 205 Group at Wadi Sharia, near Beersheba, Palestine.

The mobile meteorological units with Army formations also made frequent moves. During the period 15 to 25 June, No. 2 Mobile Met. Unit (Eighth Army) moved from Tobruk to Buq Buq, then west and south into Libya and later withdrew eastwards to a position south of Mersa Matruh; on the 25 June the unit was transferred from XIII Corps to X Corps and on 27 June to Headquarters, R.A. XXX Corps. No. 3 Mobile Met. Unit was attached at first to 94th Heavy A.A. Regiment and later to Gun Operations Room, No. 211 Group R.A.F.; on 14 June the unit moved from Gambut to L.G. 75, some thirty miles south of Sidi Barrani; subsequently the unit was evacuted with the rear party and reached Maaten Bagush on 24 June and was withdrawn later to Heliopolis.

The frequent changes in the locations of military formations necessitated frequent movements of subsidiary forecast units. Every effort was made to locate forecast units where they would be of the greatest possible use even if

the locations were of a temporary nature. The mobility of some of the units, although there was no establishment for transport for any of the meteorological units in the Command, proved of inestimable value.

In view of the grave military situation, all units in Egypt were told to be ready to move at 12 hours' notice; evacuation schemes were prepared and transport provided; instructions to destroy all non-essential documents were issued, as a precautionary measure, much of the meteorological equipment was dispersed from the main stores at R.A.F. Station Heliopolis to Rear A.H.Q., Levant, H.Q. No. 241 Wing (Syria), and to R.A.F. Station Ramleh.

Eventually the front line became stabilised in the El Alamein area and efforts were made to build up the meteorological organisation in the whole of the Middle East Command in preparation for the next offensive. The Meteorological Flight at Heliopolis was moved to Almaza where it could operate more freely and a new Meteorological Flight, No. 1415, was formed at Habbaniya on 18 July. Personnel shortages were still considerable but the training and remustering to meteorologist of additional airmen was being undertaken at meteorological units in Egypt, Palestine, Iraq, Cyprus, Aden and East Africa, and materially relieved the acute shortage of assistants.

In August approval was obtained for the designation of forecast units, as well as mobile meteorological units, by numbers and not by parent units. This saved much unnecessary work as each of the frequent changes of the parent units involved the re-posting of meteorological, signals and M.T. personnel; moreover the units had more freedom and efficiency as independent numbered units and could have their own establishments of personnel, equipment and transport.

In the interval before the British offensive opened in October 1942 the meteorological organisation was further developed and improved. Upper air charts for 10,000 and 20,000 feet were prepared daily from 1 October by the Central Forecast section, (No. 1 (M.E.) Met. Unit) Almaza and details supplied by W/T to all subsidiary forecast units. A most important development was the provision of a 15-cwt. Signals Specialist vehicle, equipped with a W/T transmitter and receiver, and manned by R.A.F., personnel, for each of the mobile meteorological units. This permitted closer contact between forward units and the parent forecast unit and avoided the difficulty, so frequently experienced in previous campaigns, of maintaining rapid and efficient signals communications between meteorological units in forward areas. On the provision of these signals facilities, broadcast transmissions were made daily from the 22 October by a high power directional transmitter at Rear Air Headquarters Western Desert for the benefit of all meteorological units in advanced positions.

At the request of G.H.Q., Middle East Forces a mobile meteorological unit was formed on 1 October for attachment to H.Q., R.A., X Corps, Eighth Army.

In preparation for an advance meteorological units were told to notify promptly changes in location; a simple code was used consisting of four 5-figure groups which were re-encyphered in meteorological one-time pads before transmission by W/T.

Meanwhile, forecasting and meteorological briefing commitments continued to increase. Special arrangements were made for the routine provision to the Commander-in-Chief's War Room at H.Q., R.A.F., M.E., of forecasts for

the battle area and for special targets, while briefings and meteorological advice were given twice daily to the A.O.C.-in-C. and Air Staffs of the R.A.F., and U.S.A.A.F. Briefings for long distance flights to the United Kingdom and Gibraltar, to Iran and Russia and for re-enforcement aircraft to Malta, were undertaken very frequently at Almaza, Cairo West and at other airfields in the Cairo area by forecasters from Almaza.

British Advance from El Alamein

An increase in meteorological personnel and equipment before the Battle of Alamein permitted a closer approximation to the approved basic meteorological organisation for the operational area. Routine weather reports were sent rapidly by W/T from advanced positions to the parent unit which supplied weather forecasts, warnings, etc., for all Royal Air Force and Army advanced units through the mobile units. The mobile meteorological units with 4th Survey Regiment, XIII Corps and X Corps, moved to advanced positions on the El Alamein line on 21 October and provided hourly or half hourly Meteor reports to the Gunners. R.A. 7th Armoured Division and the Counter Battery Officers attributed the success of the artillery barrages at Alamein in no small measure to the accuracy of the Meteor telegrams.

After the offensive had begun, the work of the forward meteorological units became very active and varied owing to the rapid retreat of the Axis forces westward, the expansion in aviation services, the increasing requirements of the Royal Navy, Army, R.A.F., S.A.A.F., and U.S.A.A.F., and the unsettled weather conditions. The Central Forecast section at Almaza supplied forward meteorological units with vital weather information. Arrangements were made for frequent broadcasts so that these units could have the latest weather reports with the least possible delay.

No. 12 Met. Forecast Unit operated with Air H.Q., Western Desert and during November 1942 moved 600 miles from Wadi Natrun to Gazala, but no break occurred in the supply of meteorological information to the units which they served. Later, the unit moved from Gazala to Regima and thence to Tripoli while the liaison meteorologist with the Advanced H.Q., moved from Regima to Marble Arch.

Arrangements were made for No. 13 Met. Forecast Unit to supply forecasts to advanced units while No. 12 Met. Forecast Unit was on the move. No. 13 Met. Unit operated with H.Q., No. 205 Group. In November the unit moved from Ismailia to Menastir (10 miles west of Bardia). The unit remained at Menastir in December providing meteorological facilities for H.Q. No. 205 Group and associated Bomber Squadrons, Royal Navy, U.S.A.A.F., and all in the Gambut-Tobruk area. In January 1943, it left Menastir for Magrun, and on 9 February proceeded to Gardabia, 18 miles south of Misurata.

No. 23 Met. Forecast Unit which was formed in August in Palestine to meet the meteorological requirements of R.A.F. and U.S.A.A.F. units there, was transferred to El Adem towards the end of December in order to provide meteorological facilities for Advanced H.Q. No. 216 Group, Royal Navy Tobruk, and other units, including U.S.A.A.F. formations, in the neighbourhood. From 20 January 1943, the unit undertook the commitments of No. 12 Met. Forecast Unit in Cyrenaica and routine reports from Tobruk, Derna and Benghazi were included in collective broadcasts.

No. 101 Mobile Unit was divided into two sections. 'A' section operated with No. 1 Composite Battery and was in action on the northern sector of El Alamein in October, on the Bir Es Suera front in December and by the end of the month was beyond Sirte. In January 1943, it operated with the 7th Armoured Division and by the end of the month was west of Tripoli. 'B' section operated with No. 2 Composite Battery and was in action on the central and southern sectors of El Alamein in October, on the Marsa Brega front in December and moved to the Marble Arch area on the 20th. In January 1943, it operated with the 51st Highland Division and was south of Tripoli by the end of the month.

No. 122 Mobile Met. Unit (XIII Corps) acted as a free lance reporting unit in forward areas when not required by the artillery. It was the first British Unit to enter the eastern perimeter of the town of Tobruk on 13 November. Later it supplied routine weather reports from Derna and Benghazi, Jedabya, Marble Arch, Nofilia and Sirte. In January 1943, the unit moved to Tripoli where it supplied routine weather reports and Meteor telegrams for G.O.R., 9th Heavy A.A. Regiment. It moved to Zuara on 6 February.

No. 123 Mobile Met. Unit (XXX Corps) moved from Alamein to Daba, Gambut, Ghemines (south of Benghazi), Marsa Brega, Nofilia, Buerat and then to 5 miles southwest of Tripoli. In February the unit was not required by the corps and then acted as a reporting unit at Beurat.

No. 124 Mobile Met. Unit (X Corps) was on the move for the greater part of November, and in December operated with the 88th Heavy A.A. Regiment, moving to Ballandah, Marble Arch, Beni Ulid, and to Tripoli; in February the unit was not required by the Corps and then acted as a reporting and distributive unit at Misurata.

It was emphasised to the Chief Signals Officer H.Q., R.A.F., M.E. in November 1942 that a rapid advance westwards would necessitate the provision of more powerful W/T transmitters to ensure prompt reception at Almaza of all routine synoptic and upper wind reports. The transmitters provided with the mobile units had a limited range and the forward subsidiary forecast units would have to act as local collective centres for all mobile meteorological units and other meteorological units in their area and to broadcast the collective reports for Almaza and other interested forecast centres. It was suggested that a meteorological W/T channel should be allocated to each main Signals Station, *e.g.* in the El Adem, Benghazi and Tripoli areas and that definite meteorological broadcast periods should be allotted to each station. Collective meteorological messages, encyphered, would then be passed by the respective subsidiary forecast units for broadcast by high powered transmitters, and could be received by Algiers (for First Army), Malta, Almaza, Tobruk, Cyprus, Jerusalem, Beirut, and subsidiary forecast units, thus ensuring no delay in the receipt of vital weather information.

As the advance continued, arrangements were made to provide meteorological assistants at important landing grounds to organise the collection of special weather reports from reconnaissance and bomber crews and to transmit the reports to Almaza and to other forecast units. A Meteorological (THUM) Flight (No. 1563) was established at Benina in December 1942. Ultimately Meteorological Flights operated at Almaza, Benghazi, Tripoli, Nicosia, Ramleh, Khartoum, Nairobi, Habbaniya, Teheran, El Geneina, Aden and Mombasa.

Broadcasts of North African collective meteorological reports were received from 26 December. Meteorological signals communications in Egypt were improved and a teleprinter link from Almaza to the forecast unit at No. 201 Group (Alexandria) was in operation from mid-December 1942.

The basic meteorological organisation changed little during the second phase of the operations (February to May 1943) apart from the establishment of an additional forecast unit (No. 14) to provide meteorological facilities in Tripolitania, the establishment of many additional reporting stations and the formation of a mobile meteorological unit for No. 36 New Zealand Survey Regiment staffed by New Zealanders trained by British in meteorological duties. In addition to the routine issues of meteorological data, forecasts, analyses, inferences, etc., by the Central Forecast Section, Almaza, to all subsidiary forecast units, arrangements were made to transmit reports on a special link to Algiers for the use of the R.A.F., and U.S.A.A.F. meteorological services in North-West Africa

No. 12 Met. Forecast Unit (A.H.Q., Western Desert) was established about two miles west of Tripoli and provided meteorological facilities for A.H.Q., Western Desert and various R.A.F. and Army formations and to 12th Bombardment Group, U.S.A.A.F. Part of the unit left Tripoli on 13 March for Advanced A.H.Q., Western Desert and provided meteorological facilities for all R.A.F., Army, U.S.A.A.F. and S.A.A.F. units in forward areas. When No. 12 Met. Forecast Unit was moved into Tunisia, a new unit, No. 14 Met. Forecast Unit (Tripoli), was formed at Tripoli to provide meteorological facilities for all units remaining in the area, to collect routine meteorological reports from stations in Tripolitania and to broadcast collective messages by W/T; it provided facilities for 57 Fighter Group U.S.A.A.F., 12th Bombardment Group, U.S.A.A.F., and to Free French Units at Ben Gardane.

No. 13 Met. Forecast Unit (H.Q. No. 205 Group) operated in the Gardabia area during this phase of the operations and moved to Kairouan on 27 May.

No. 23 Met. Forecast Unit (El Adem) moved temporarily to Berka, but on the establishment of a U.S.A.A.F., Weather Service at Benina, returned to its original location at El Adem. It was responsible for the provision of meteorological facilities in Cyrenaica, and for the collection and re-transmission to Almaza of routine reports from stations in Cyrenaica. It supplied meteorological facilities to U.S.A.A.F., detachments at Benghazi and at Gambut.

No. 101 Mobile Met. Unit (4th Survey Regiment) was in action at W. Akarit during the first week of April, and then south of Enfidaville until cease fire on 13 May.

No. 122 Mobile Met. Unit (XIII Corps) moved to Ben Gardane, Medenine, Gabes, and eventually arrived at Tunis on 8 May; routine synoptic reports were sent from Tunis from 0900Z on the 10th.

Nos. 123 and 124 Mobile Met. Units were not required for artillery purposes during this phase of the operations and remained as reporting units at Buerat and at Misurata respectively.

Two meteorological officers were posted in March 1943 from Middle East to Algiers to assist the North West African Meteorological Service.

In May 1943 a forecast unit was established at Cairo West airfield with a teleprinter link to Almaza; and three new Mobile meteorological units, Nos. 125, 126 and 127, were formed at Heliopolis to meet the needs of the Army in projected operations in Sicily and Italy.

During the whole of the operations very close liaison was maintained with other Services including the Ninth U.S.A.A.F.

After the cessation of hostilities the meteorological organisation in Libya comprised :—

No. 14 Met. Forecast Unit (Castel Benito), responsible for the meteorological organisation in Tripolitania.

No. 23 Met. Forecast Unit (El Adem), responsible for the meteorological organisation in Cyrenaica.

Reporting stations at Kufra, Tobruk, El Adem, Derna, Barce, Benghazi, Marble Arch, Misurata, Buerat, Suara, Nalut, Castel Benito.

Meteorological (THUM) Flights at Benina and Castel Benito.

Invasion of Sicily and Italy

In the spring of 1943, plans were made to provide meteorological facilities for Middle East Army and Royal Air Force units destined for the invasion of Sicily and Italy. The Middle East contingent included both forecast units and mobile meteorological units. C.Met.O., Middle East visited Algiers from 17 to 24 June, for discussions with C.Met.O., N.A.A.F., and with Army and R.A.F. Planning Staffs at H.Q., 141 Force. During this visit arrangements were made for the provision of a mobile meteorological unit for 51st Division by C.Met.O., N.A.A.F., and for close liaison and co-operation between the meteorological units provided by N.A.A.F. and by H.Q., R.A.F., Middle East.

No. 12 Forecast Unit embarked with Advanced A.H.Q., Western Desert on 19 June, and disembarked at Malta on 21 June, while No. 127 Mobile Met. Unit was held in reserve at Rear A.H.Q., W.D., until it landed at Salerno in September, it was attached to 46th Division.

Nos. 125 and 126 Mobile Met. Units disembarked in Sicily with foremost Army Units on 10 July, and were attached to XIII and XXX Corps respectively. Weather reports were issued on the same day and Meteor reports were supplied in accordance with artillery requirements. No 12 Met. Forecast Unit embarked from Malta on 16 July, and disembarked at Syracuse on 17 July, observations being made from 1600Z that day at 3711 N. 1512 E.

From 1 October 1943, all Middle East meteorological units operating in Sicily and Italy, comprising No. 12 Met. Forecast Unit, and Nos. 125, 126 and 127 Mobile Met. Units, were transferred to the administrative control of Chief Met. O. N.A.A.F.

In July 1943, an officer instructor arrived in Cairo from the United Kingdom and forecast training courses began on 1 September. Each course lasted approximately three months and arrangements were made to train as forecasters suitable meteorological airmen, not only from the Middle East Command but also from the Mediterranean and Indian Commands.

Facilities provided for Transport Command[1]

In 1940 and 1941, a considerable flow of aircraft re-inforcements developed on the Takoradi route from West Africa to the Sudan and then northwards to Egypt, and notes on meteorological conditions along various sections of the route were prepared.

[1] A.M. File S.62220.

A meteorological assistant was posted to R.A.F. Staging Post, Wadi Halfa, in May 1941, to assist in the supply of meteorological information to R.A.F. convoy pilots, prior intimation being given to the Government Meteorologist, Sudan, who maintained a meteorological reporting station at Wadi Halfa staffed by Sudanese observers.

In July 1942, No. 216 Group was formed at Heliopolis, in order to control movements of re-inforcement and transport aircraft to and through the Middle East Command and to develop new and existing routes in Africa and in other areas under the operational control of H.Q., R.A.F., M.E.

The main transport and ferry routes were across Central Africa from Lagos to Khartoum, Aden and Karachi, and, after the liberation of the north coast of Africa, from Rabat Sale or Casablanca to Maison Blanche (Algiers), Castel Benito, Cairo West, Habbaniya and Karachi. On the former route, meteorological facilities were provided mainly by the Royal Air Force and U.S.A.A.F. In the Sudan, the R.A.F. maintained forecast services at El Geneina, El Fasher and Khartoum, although for a time there was an American forecaster at El Geneina to deal with purely U.S.A.A.F. requirements. Wadi Seidna was manned jointly by R.A.F. and U.S.A.A.F. forecasters at first, but later the Americans undertook the main forecasting duties until the flow of aircraft decreased and No. 20 Staging Post, R.A.F., was transferred to Khartoum airfield. At Asmara a Royal Air Force forecast service was maintained helped for a time by the American weather service.

At airfields on the South Arabian route, there were joint R.A.F.–U.S.A.A.F. Meteorological offices but forecasting facilities were provided mainly by the U.S.A.A.F. at Khormaksar, Masira and Salala, until the Americans withdrew in early 1945.

On the North African route forecasting commitments were undertaken by the forecast units provided originally for operational commitments. As the Transport Command services expanded, a special organisation became essential and the Assistant Director for Overseas Services from Meteorological Office, Headquarters surveyed the route at the end of 1943 and reported on the meteorological facilities required.

During 1944, the volume of traffic through Rabat Sale, Maison Blanche, Castel Benito, El Adem, Cairo West, Habbaniya, Shaibah and the Persian Gulf stations became heavy, and continuous 24-hour forecast services were provided, primarily to meet these commitments. At the joint user airfield at Maison Blanche the meteorological facilities were provided by the Americans, but later a British forecast service was provided to meet the needs of the R.A.F. ; while at Bahrein all the meteorological requirements were met by the Americans.

With the successful development of operations in France the work of Transport Command became increasingly the transport of troops and supplies, and flights could be made along more direct routes. An increasingly complex network of scheduled air services developed within the operational theatre and by the end of 1944, No. 216 Group had over 60 Staging Posts at airfields spread over the area from Rabat Sale to Sharjah and from Central Italy (later Austria) to Nairobi. At most of these staging posts the meteorological facilities were provided through the R.A.F., *i.e.* by the Air Ministry Meteorological Service.

The activities of No. 216 Group, which was controlled operationally by H.Q., Transport Command, spread over several commands, *e.g.* M.A.A.F. in the west and north Mediterranean and M.E. in the south and east Mediterranean, Iraq, Persian Gulf, Sudan, Eritrea and South Arabia; differences in meteorological organisations and procedures were inevitable. In February 1945, a Senior Meteorological Officer was posted to H.Q. No. 216 Group, to advise the A.O.C., and to ensure that a satisfactory and uniform meteorological service was provided for transport Command. To implement this policy, he visited all main units under the control of No. 216 Group during the first half of 1945 and, by arrangement with the respective Chief Meteorological Officers, ensured that standard briefing procedures and forms were in use in the area. Half-hourly broadcasts of weather reports on 4,700 Kcs were inaugurated at all main airfields; in-flight weather reports were organised from Transport Command aircraft, and later extended to non-Transport Command aircraft. In addition a valuable liaison visit was made to H.Q. No. 229 (Transport) Group in Delhi.

In 1945, Area Control Centres were established at Malta, Cairo, Habbaniya, Rabat Sale, Aden, Khartoum and Nairobi and at each centre adequate meteorological forecast services and advice were provided.

The end of the war coincided with the biggest effort of No. 216 Group. The rapid transportation of troops from the European to the Far East war zones had been planned and adequate meteorological facilities had been arranged, but the main airlift of troops was reversed, and personnel were brought back from the Far East to the United Kingdom. This was the final large scale transport operation in the theatre and lasted until March 1946.

Control of Meteorological Services in Eritrea, Italian Somaliland and Abyssinia (Ethiopia)

After the defeat of the Italians and the occupation of Italian Somaliland, Eritrea and Abyssinia, the Senior Meteorological Officer, Aden surveyed the meteorological requirements in the occupied territories and made recommendations to Air Ministry for the re-organisation of meteorological services in these ex-Italian territories. The recommendations envisaged a network of meteorological stations to meet general meteorological requirements in Africa, and a forecast service sufficient to meet the requirements of transport flights. In general the locations chosen for the meteorological reporting stations were those where British Political Officers were located so that adequate signals facilities and the necessary supervision of any native staff could be assured.

At the end of November 1941, it was decided to establish in Eritrea a forecast office at Asmara, and reporting stations at Nacfa, Agordat, Tessenei, Massawa and Assab; for Italian Somaliland it was proposed to establish meteorological reporting stations at Mogadishu, Obbia, Dante or Allula, and Bardera or Lugh Ferrandi; staff for Asmara and Mogadishu would be mainly British with some natives while the remaining stations would be manned by natives.[1]

After his appointment in the summer of 1942, the Senior Meteorological Officer of H.Q. No. 203 Group, Khartoum, visited Eritrea and submitted a report and recommendations on the reorganisation of the meteorological service in Eritrea to Air Ministry, and in February 1943, Air Ministry took

[1] A.M. File S.74969.

over control of the Eritrean Meteorological Service from the Occupied Enemy Territory Administration. It was agreed that Air Ministry would be responsible for :—

(*a*) the payment of the meteorological staff at Asmara;

(*b*) the payment for part-time meteorological observers (native) at the meteorological reporting stations;

(*c*) the payment of a small sum monthly to 25 rainfall observers and to two observers of the Department of Agriculture, subject to the receipt of satisfactory summaries of observations by the Meteorological Office, Asmara.

A forecast service was established at Asmara and routine weather reports were sent from Adi Ugri, Adi Caieh, Agordat, Cheren, Ghinda, Massawa, Nacfa and Tessenie (replaced subsequently by Assab), by telephone to Asmara. Collective weather messages were broadcast by the R.A.F. W/T at Asmara.

In November 1942, the Senior Meteorological Officer at H.Q. No. 207 Group, R.A.F. (Nairobi) visited Mogadishu and arranged for clerks employed by the District Commissioners to be trained as part-time meteorological observers at Belet Uen, Kismayu, Dante, Bardera, Iscia, Bardua and Gabredare, and for R.A.F. Wireless Operators at Lugh Ferrandi, Gerrahei and Giggia to be trained as meteorological observers. Soon afterwards the Air Ministry assumed control of the British East Africa Meteorological Service and C.Met.O., East Africa became responsible for the meteorological organisation in Italian Somaliland, south of latitude 8° North. In January 1943, it was agreed that a Meteorological Officer and an assistant should be posted there. Subsequently arrangements were made for the transmission by Army W/T channels of routine reports from selected meteorological stations to Mogadishu, the transmission by W/T of collective messages from Mogadishu to A.H.Q., East Africa and the inclusion of the reports in the meteorological broadcasts from Nairobi.

Co-operation with the U.S.A.A.F. in the Middle East

From December 1941, frequent discussions were held at H.Q., R.A.F., M.E., and at the Central Forecast Section (No. 1 (M.E.) Meteorological Unit) Almaza, with Weather Officers and staff of American Ferry Command, Pan American Airways, American Missions and U.S. Army Air Corps regarding meteorological organisation in the Middle East and there was co-operation for the provision of meteorological facilities to American units.[1] From June 1942, after the arrival of the Regional Control Officer and Staff Officers of the 19th Weather Region U.S.A.A.F. and of the Ninth U.S.A.A.F., it was agreed that, as far as possible, no meteorological services should be duplicated and that, in places where British meteorological services already existed, any American weather personnel should be employed to augment the local services as necessary. It was also agreed that at Staging Posts used jointly by the R.A.F. and U.S.A.A.F. there should be combined weather offices, but normally each service would provide meteorological facilities, briefing, etc., for its own pilots and aircrews.

American personnel began to arrive in various parts of Middle East from April 1942, but until the beginning of 1943 they depended almost entirely on British staff for meteorological facilities. In April 1942, American forecasters

[1] A.M. File S.90334.

arrived at Almaza and were given facilities for plotting weather maps and other meteorological duties. Similar arrangements were made in Palestine, Habbaniya, Bahrein, Abadan, Teheran, Wadi Seidna, El Geneina and Asmara. For the attacks on the Ploesti oilfields by U.S.A.A.F., bomber aircraft in June 1942, all meteorological information was supplied by British staff, and on 10 and 11 June, a British meteorological officer from Almaza was flown to the U.S.A.A.F. base airfield to give meteorological briefings to the American aircrews.

From August 1942, frequent meetings were held with the U.S.A.A.F. Staff Weather Officers and arrangements were made to provide meteorological facilities for all American flying units, to attach U.S.A.A.F. weather personnel to British meteorological cyphers to U.S.A.A.F. Weather units ; it was agreed that the C. Met. Officer, H.Q., R.A.F., M.E., would be notified of all projected changes in the U.S.A.A.F. weather organisation in the Middle East.

Meteorological forecasts and briefings were provided by British forecast units to various U.S.A.A.F. units in Palestine, in the Gambut and other areas, throughout the whole of the operations from Alamein to Tunis.

Early in 1943 the C. Met. Officer, H.Q., R.A.F., M.E., gave daily meteorological briefings to Staff Officers of the Ninth U.S.A.A.F., and for several months a British meteorological officer and assistant were attached to this American unit after it moved to Benghazi in order to ensure maximum co-operation and liaison.

From April 1943, the British forecast unit at Tripoli supplied basic weather data, analyses, forecasts, etc., to a joint R.A.F., S.A.A.F., U.S.A.A.F., forecast unit at Castel Benito and after the American personnel departed in November 1943, it provided all meteorological facilities for American aircrews at Castel Benito.

In Eritrea the American meteorological personnel were established at Gura (30 miles S.S.E. of Asmara) from June to November 1943, but all basic weather data and forecasts were supplied to them by the British forecast unit at Asmara. In November 1943, the American Weather Unit moved to Asmara and a joint service was maintained until May 1945, when the American unit was withdrawn and all meteorological facilities were provided by British personnel.

In the Sudan, American units arrived at Wadi Seidna in June 1942 ; joint meteorological facilities were provided until April 1943, after which Americans provided their own forecasts, the basic weather data being obtained from Khartoum. At El Geneina a joint meteorological office was operated by the R.A.F. and U.S.A.A.F., while at El Fasher all the meteorological facilities were provided by British staff. All American units were withdrawn in June 1945.

Similar assistance and co-operation occurred in other parts of the Middle East Command, particularly along the South Arabian route at Aden (Sheikh Othman) Masira and Salala, in Iraq and Iran, in the Persian Gulf and at radio-sonde and radio units at Nicosia (Cyprus) where joint arrangements were made for accommodation, transport, stores and signals facilities during the period in which the U.S.A.A.F. unit operated from June 1944 to August 1945.

As the numbers of U.S.A.A.F. Weather personnel and the supply of American meteorological instruments and equipment in the Middle East increased during the years 1943 and 1944, much help was given by H.Q. 19th Weather Region

U.S.A.A.F., in establishing and maintaining meteorological reporting stations in the Middle East Command. The reception and transmission of basic meteorological data were primarily the responsibility of British forecast units, but the Americans gave valuable help in the provision of personnel at many stations and in the provision of meteorological equipment, particularly hydrogen generators and teleprinters, of which not enough were available from British resources to meet the increasing needs of the British meteorological service.

Forecasting Problems

The outstanding forecasting problem in the Middle East was that of predicting upper winds in low latitudes. The mathematics of the relation between wind and pressure distribution had not been solved and empirical methods, such as charts of stream lines and extrapolation therefrom, had to be used.

The accurate forecasting of cloud amount and height over high ground, *e.g.* in the Balkans, was also difficult and pointed to the need for research on the effect of high ground on the upper distribution of pressure and temperature and on wind flow and turbulence.

Another problem was that of the origin and effect of upper air instability with which the development of thunderstorms and duststorms is often associated.

Finally, there were the problems of the nature and behaviour of the so-called inter-tropical front or convergence zone which constitutes the meeting-place within the tropics of air masses originating from north and south of the equator and of the peculiar surges of pressure which occur within these regions.

CHAPTER 21

NORTH-WEST AFRICA, ITALY, THE BALKANS AND SOUTHERN FRANCE

Planning for Operation Torch

The planning of the meteorological organisation for operation Torch began towards the end of August 1942. Planning for the operation as a whole was then well advanced and the intrusion of complex meteorological requirements caused adjustments in other preparations which were otherwise nearing completion. A British meteorological section was provided at the planning H.Q., and was joined by a section of the 12th U.S.A.A.F. Weather Squadron. The latter were concerned with the area west of Algiers which was to be occupied following the American landings at Oran and Casablanca, while the British section dealt with the area from Algiers eastwards. Each meteorological service was to be organised and controlled separately, but arrangements were made for full technical collaboration between them.

The size and structure of the forces to be deployed in the operation largely determined the details of the meteorological organisation required, but there were some special features owing to the remoteness of North-West Africa from areas of Allied occupation where elaborate meteorological services already existed. The nearest of these services were in the United Kingdom and the Middle East, but the distances were too great to permit of the meteorological organisation for Torch being planned as an appendage of one or the other. Moreover the reaction of the French to the landings was in some doubt and, even if they did declare for the Allies and thus bring to their assistance an extensive territorial meteorological service, it could not be assumed that it would be able to function to the necessary degree of efficiency. It was necessary therefore, that the British meteorological organisation should be as self-contained as practicable with a central unit that would collect and distribute basic data and, in addition, supply subordinate sections with technical guidance in the form of detailed analyses and forecasts. The Americans adopted a similar arrangement. Any French observing stations within territory that came under Allied control were to be incorporated in the British or American reporting networks.

The British forces taking part in the North-West Africa landings were to consist of the First Army, with V and IX Corps, and Eastern Air Command which was to control, in addition to a Group Headquarters, four Fighter Wings, a Light Bomber Wing and a General Reconnaissance Wing. The meteorological section at H.Q. Eastern Air Command was to form the H.Q. of the British meteorological service, controlling technically and, where necessary, administratively, all the meteorological sections of other formations; it was to act as the Central Forecasting Section for the area occupied by the British Forces and would issue at fixed times to all meteorological units, collective messages containing basic data, analyses and forecasts. A Type 1 meteorological unit was to advise the A.O.C. and staff of No. 242 Group H.Q. and issue

detailed forecasts covering the operational area of the Group ; this unit would have technical control, subject to the general guidance issued from the meteorological section at H.Q. Eastern Air Command, of Type 3 units at H.Q. 326(B) and H.Q. 328(G.R.) Wings and a Type 4 unit at H.Q. Fighter Wing. These Type 3 and 4 units would receive detailed forecasts from the Central Forecasting Section or parent Type 1 unit for supply to Wing H.Q. and squadrons. A Type 1 unit was to provide forecasts and advice to the ' G ' and 'Air ' branches of the Staff at H.Q. First Army and for any special requirements for chemical warfare or smoke operations ; it would also be in general control of the meteorological units at Corps H.Q. and those attached to Survey Regiments, R.A. Type 2 units were to provide forecasts and advice to the staff at H.Q. V and IX Corps and deal with any special requirements for chemical warfare and smoke operations ; they would also provide Meteor reports for Artillery Units within the Corps area except when the meteorological units attached to Survey Regiments could meet that commitment. No. 5 and No. 8 Survey Regiments, R.A. were to be provided with specialised meteorological units whose main task was to supply information and advice on the meteorological aspects of sound ranging ; these units were also to provide Meteor reports to the neighbouring Artillery units.

Communications

The communications requirements of the various meteorological units were based on their complete dependence on wireless for the reception of basic data. This course was adopted because units were not expected to become static for some time after the campaign opened and because it was understood that the existing landline communications in North-West Africa were ill-developed and that none were available for the exclusive use of the local meteorological service. The U.S.A.A.F. Weather Squadron planned to develop their own meteorological teleprinter network and it was intended that the R.A.F. meteorological units which became static would be connected to this system with a resulting economy in the use of wireless.[1]

The amount of basic data that could be obtained from important areas outside the theatre of operations was limited because most European countries were under enemy occupation and their weather reports were denied to the Allies. Spain and Portugal, as neutrals, were broadcasting in clear collected observations relating to their own territory. The Air Ministry transmissions gave all available data for the British Isles, Iceland and Atlantic, whilst Almaza broadcast reports collected from the Middle East region ; the routine issues from Gibraltar and Malta were restricted to local observations of surface and upper air conditions. The Central Forecast Section at H.Q. Eastern Air Command was to receive the complete programme of these broadcasts and the other units were to intercept all the Spain, Portugal, Gibraltar and Malta issues and selections from the Air Ministry and Almaza transmissions. Special broadcasts from H.Q. No. 333 Group would supplement the information received by the remaining units.

For the collection of reports of the weather within the area of operations, the meteorological sections of R.A.F. and Army formations were to form a network of observing units. Reports were to be made every three hours and

[1] A.M. File S.86093.

sent by the most convenient means to H.Q. Eastern Air Command. As an additional source of weather reports, it was arranged that pilots should, in the course of operational sorties, make observations of wind, cloud, weather and visibility. These reports were to be passed to the nearest meteorological unit as soon as possible after landing and thence forwarded to H.Q. Eastern Air Command.

All reports received at H.Q. Eastern Air Command were to be assembled into weather messages for broadcast at fixed times. The 12th Weather Squadron were to make similar arrangements for collecting reports from their units and there was to be a complete exchange of information between their H.Q. and H.Q. Eastern Air Command.

In order to ensure the reception of all the data required, it was estimated that wireless facilities should be provided for the meteorological sections according to the following scale :—

H.Q. Eastern Air Command	3 reception, 1 transmission channels.
H.Q. No. 242 Group and H.Q. 1st Army.	2 reception channels (and 1 transmission channel for 1st Army).
Corps H.Q.s	1 reception channel, 1 transmission channel.
Wing H.Q.s	1 reception channel.

The units with Survey Regiments, R.A., would not require special wireless facilities.

Since a high degree of security was attached to weather information, the interception of all these broadcasts, except the *en clair* transmissions from Spain and Portugal, called for an intricate distribution of cyphers among the R.A.F. and U.S. meteorological sections. Of the various confidential and secret documents, the initial distribution alone amounted to more than 30 sets.

Equipment

The technical equipment supplied to meteorological units was in general limited to the instruments necessary for making the usual observations of temperature, humidity, pressure and cloud movement, but two of the meteorological units with Wing H.Q. and those attached to Army formations were also provided with equipment for measuring upper winds by pilot balloons. The nature of the operation did not allow the transport of elaborate apparatus ; for example, aneroid barometers had to be supplied instead of the more accurate mercury barometers.

The equipment was packed in sets so that each set could travel on the same convoy as the unit for which it was intended. Some additional equipment was packed for the H.Q. Eastern Air Command meteorological section, which was to become the main store for replacements of broken instruments and consumable stores.

Transport

For the meteorological units attached to the Army the need for transport facilities had to be specially considered. All Field Army Units were self-contained and completely mobile and it was essential that their meteorological sections should operate on a similar basis. To ensure complete mobility, the

meteorological sections of H.Q. First Army and H.Q. V Corps and H.Q. IX Corps were provided with a 3-ton lorry, a 2-seater car, a motor cycle and a 15-cwt. wireless truck—the last item being supplied by the R.A.F. ; meteorological units attached to Survey Regiments, R.A. were provided with two 15-cwt. trucks and a motor cycle.

Initial Arrangements

Special arrangements were made for the supply of forecasts and advice during the very early days of the campaign, that is, the period from about D minus 6 to D plus 5. During this period an advanced element of Allied Force Headquarters was to be located at Gibraltar in the Area Combined H.Q. which already had a Type 1 meteorological office. This office issued routine forecasts covering the Western Mediterranean and the Western Approaches to the Straits of Gibraltar and Fleet synoptic messages to ships of the Royal Navy operating in those waters. It was therefore convenient for the Supreme Commander and the Navy, Army and Air Commanders to rely on the forecast unit at Gibraltar for weather information during the initial phase of the operation.

In view of the importance of the forecasts to be issued by Gibraltar during this period, Coastal Command were requested to arrange daily meteorological reconnaissance flights to two positions in the Atlantic. One flight was to operate from Gibraltar to about 38° N. 17° W., while the other would be based at St. Athan and make observations to about 45° N. 17° W. The information obtained from these flights, taken with the data already available, would enable the forecasters at Gibraltar to improve the accuracy of the forecasts for the fly-out of aircraft from United Kingdom to the theatre of operations.

To provide more detailed advice at Algiers for the early landings, it was decided that the Chief Meteorological Officer should travel on the Headquarters Ship of the Eastern Task Force, *H.M.S. Bulolo*. On *Bulolo*, charts were to be drawn based on weather messages received from Air Ministry and Gibraltar. The Chief Meteorological Officer would thus be able to advise the Navy, Army and Air Staffs on *Bulolo* and supply forecasts to the Fighter Controllers who were to direct the operations of the squadrons.

As a further measure of assistance to Gibraltar and to the Chief Meteorological Officer on *Bulolo*, the Central Forecasting Office at Dunstable was to pay particular attention to the Western Mediterranean during this period and to add to their general inferences, broadcast twice daily, a message giving the anticipated developments on the weather situation around the North African Coast. These messages were in a special cypher, of which there were only three copies, one for Dunstable, one for Gibraltar and one for *Bulolo*.

Early Stages of the Campaign

The first convoy, led by Headquarters Ship, left Greenock on 25 October 1942. In the first few days of the voyage, the wireless operators were given plenty of practice in the reception of weather broadcasts from Air Ministry, Spain, Portugal and Gibraltar ; the plotting of two charts per day, the 0700 and 1800 G.M.T. was started.

It was soon found that the transmission from Spain and Portugal, although audible, were very difficult to read. Observations for the Iberian peninsula and the Azores were therefore obtained from the Gibraltar Fleet synoptic

messages which repeated the Spanish and Portuguese broadcasts, but this alternative source was not satisfactory because of the lateness of the transmissions.

During these early days, from about D minus 2 onwards, the most difficult forecasting was concerned with the naval operations. After Algiers had been occupied, further landings were made eastwards along the coast at Philippeville and Bone and at intermediate points ; freshening winds raised heavy seas and the use of small boats was extremely hazardous.

The forecasting for land and air operations was comparatively simple at this time because the conditions were almost perfect. In fact, 78th Division, the first force to land, had pushed so far ahead as to be beyond the reach of up-to-date weather forecasts. The main problem was to keep the squadrons informed of the wind speed at all levels to 20,000 feet and various measures were adopted to impart the information, the most satisfactory being to ask the duty Control Officer on *Bulolo* to read the forecast to the pilots as soon as they were airborne.

Meanwhile negotiations were being conducted with the French. Regular reports were still being received over the public telephone system from a reasonable network of stations in Algiers, Tunisia and Morocco and it was readily agreed that these observations should be supplied to the R.A.F. and arrangements for their collection were made.

The broadcasting station FOG which, up to D Day, had been used for the transmission in French cyphers of North-West African weather reports had been closed down by the Allies immediately control of Algiers had been secured. Application was therefore made for the station to be re-opened under the supervision of the Chief Meteorological Officer for broadcasts of weather data in British cyphers ; authority to re-open the station was received on 21 November (D plus 13). A schedule of broadcasts was started on the following day.

On 12 November four meteorological units arrived with the second convoy. These were the meteorological sections of H.Q. Eastern Air Command, H.Q. First Army and of Nos. 326 (L.B.) and 328 (G.R.) Wings. Since the meteorological section of H.Q. Eastern Air Command was to be the principal forecasting and distributing centre for the whole theatre, it was essential that it should function efficiently at the earliest possible moment, and by about 17 November the unit was receiving all available data and was able to supply forecasts to all who required them. Meanwhile forecasts were issued from *Bulolo* by the Chief Meteorological Officer, who had been joined on board by one of the meteorological officers who arrived on the second convoy.

Formation of the Central Forecast Section

At H.Q. Eastern Air Command the meteorological unit was from the beginning organised in two sections. One dealt with the administration of the British meteorological service in the theatre, with the planning for future developments and operations, and liaison with other services ; the other concentrated on forecasting and the collection and dissemination of meteorological information and was referred to as the Central Forecasting Section. The Central Forecasting Section (C.F.S.) was set up at Maison Caree in the same building as the whole Headquarters of Eastern Air Command. Weather

information for the areas outside the theatre was obtained on three reception channels and routine reports from units in the theatre were collected, either directly or indirectly, by telephone.

Initially it was decided that the transmitting schedule should include a selection of British and European data but as it was learned that reception of the French station FOG (from which the collected reports of French stations in North-West Africa were broadcast) was generally bad, the broadcasting schedule of the Central Forecasting Section was further extended to include this data. Eventually C.F.S. was transmitting, besides forecasts and analyses, all American, British and French reports for North-West Africa, and repetitions of the Madrid, Lisbon, Gibraltar and Malta synoptic issues. By this means units at lower formations could receive most of the data they required on one interception channel from one transmitting channel. Meanwhile the 12th Weather Squadron was developing a teleprinter network by means of which its units would be fed with basic data from a Headquarters collecting centre. It was convenient therefore to include the Central Forecasting Section in this teleprinter network. Thus all the data obtained at the C.F.S. by wireless interception were transmitted on the teletype to all U.S.A.A.F. weather units. For their part the Americans, who were in Algiers near to the French Meteorological Headquarters, were able to provide the R.A.F. with the reports from French stations in North-West Africa more quickly than had been possible before.

The chief difficulty at the C.F.S. at first was that the region was comparatively little known to the meteorologists. Such climatological summaries and other technical literature as were available for North-West Africa were based on very inadequate data. There were few reporting stations inland and although there was a good distribution of stations along the coast, the weather there was quite unrepresentative of the weather in the region as a whole. In the beginning therefore forecasting work was allied to an intensive study of the weather peculiarities of the area.

Development of the Meteorological Organisation in North-West Africa

From the opening of the campaign in November, the meteorological organisation that had been planned for Torch gradually took shape and by about mid-January 1943 the various units were operating more or less efficiently with the formations to which they were assigned. A certain amount of re-planning was soon needed however. The forces from Egypt had advanced from El Alamein and entered Tunisia early in the new year and it was decided that all the military and air forces engaged in the battle for Africa should be joined under one Command. A new formation, the Northwest African Air Forces, was created. The organisation of the meteorological service had then to be re-adjusted to conform with the new military structure and liaison with the U.S.A.A.F. Weather Squadron had to become even closer. Early in February 1943, the meteorological service was re-organised as follows:—

H.Q. Northwest African Air Forces (N.A.A.F.) (later H.Q. Mediterranean Allied Air Forces).	H.Q., R.A.F. Meteorological Service with a Central Forecasting Section.
H.Q. Northwest African Tactical Air Force (N.A.T.A.F.) (later H.Q. Mediterranean Allied Tactical Air Force).	Type I Meteorological Office; collecting centre, with subsidiary units.
H.Q. Northwest African Coastal Air Force (N.A.C.A.F.) (later H.Q. Mediterranean Allied Coastal Air Force).	Type I Meteorological Office with subsidiary units.
H.Q. Northwest African Strategic Air Force (N.A.S.A.F.) (later H.Q. Mediterranean Allied Strategic Air Force).	Meteorological Liaison Officer at H.Q.; Type I office with No. 205 Group; subsidiary units at Wings.

Later in the war the organisation was further expanded owing to the creation of such formations as Balkan Air Force.

The Central Forecasting Section (C.F.S.) remained at Maison Carree, Algiers until August 1943, when it moved to advanced H.Q., N.A.A.F. at La Marsa near Tunis where it operated with its own separate signals office containing five W/T reception channels, two transmission channels and a teletype link on the American network. The broadcast traffic from C.F.S. amounted to some 10,000 groups a day, which were intercepted as far away as United Kingdom, Middle East and West Africa. To ensure good reception, equipment for automatic transmissions was installed. By the time the move to La Marsa occurred area forecasts were being issued for Morocco, Algeria, Tunisia, Sicily, Italy and relevant sea areas. The scope of the Analyses and Baratics was much increased and the issue of upper air contour charts for 500 mbs. was begun.

To ensure the proper co-ordination of the forecasting service for the whole theatre it was decided early in 1944 to form a combined centre where British and American personnel worked side by side and issued agreed advice to all units. This centre was formed in Bari at the Headquarters of the 15th U.S.A.A.F. towards the end of March 1944; The C.F.S. moved from La Marsa to Bari by air. Close collaboration was maintained between the British and American personnel and the decision to form this combined centre was undoubtedly a success. The centre functioned until July 1945, after which it was no longer required for its original purpose and was disbanded; the R.A.F. element was transferred to Malta.

N.A.T.A.F. in North-West Africa

The formation of the meteorological section of H.Q. Tactical Air Force was a completely new departure inasmuch as this forecast section was to meet the needs of an Army Group, the 18th, as well as those of N.A.T.A.F. The section formed at Constantine at the beginning of March 1943 and began to supply forecasts to the Army and Air Staffs and to the Operations Room. The unit was concerned with the supply of weather information both for air and ground operations each of which presented special problems. The combined hazards of the weather and the mountains had to be appreciated, yet any tendency to undue caution avoided, since every flying hour was valuable if the enemy were to be not only defeated but also prevented from escaping. An all-out effort meant choosing conditions suitable for both strategic and tactical aircraft, while the Army, though less exacting in detail, was naturally concerned that the forecasts should cover a wide range of time.

Another important role of the meteorological section of H.Q., N.A.T.A.F. was that of liaison with the meteorological sections of the various formations under the command of N.A.T.A.F. and Eighteenth Army Group. For several

months the H.Q. unit was too small to assume either technical or administrative control over these other units and in the interests of co-ordination, adequate liaison was a vital matter. The units concerned were with the following formations :—

H.Q. First Army		*H.Q. 242 Group*
H.Q. V Corps	H.Q. IX Corps	H.Q. Tactical Bomber Force.
No. 5 Survey Regiment.	No. 8 Survey Regiment.	H.Q. No. 232 Wing.

Communications in the battle area were largely centred on H.Q., N.A.T.A.F. and Eighteenth Army Group and requests for weather information filtered through to the meteorological section which was soon supplying forecasts to Allied Force H.Q. (Advanced), H.Q. 2 (U.S.) Corps, Gun Operations Room and Communication Flights. The unit also became an exchange point for weather reports from the battle area. These came in singly or in twos and threes and were ultimately distributed in collected form both to the meteorological units within N.A.T.A.F. and to the C.F.S. which broadcast the data to a wider audience.

As the final days of the battle for Tunisia arrived, the N.A.T.A.F. meteorological unit had its efficiency tested by mobility. The first move from Constantine was to Ain Beida on 11 March, the next to Haidra on 10 April and finally to Le Kef nine days later.

Widespread thunderstorm activity marked the preparation for the final onslaught but conditions improved greatly on 7 May and the battle for Tunis was joined. That day the Tactical Air Force carried out over 2,000 sorties and within five days Tunis fell.

First Army.—After its arrival in Algiers, the first move of the First Army was to Constantine with Advanced H.Q. The H.Q. of the American 12th Air Force (Bomber Command) formed here early in December and collaboration between the meteorological section of this H.Q. and that of H.Q. First Army benefited both. Close liaison was maintained with the Chemical Warfare Staffs who were occupied with the peculiar topographical problems involved in the smoke-screening of the ports Bougie, Philippeville and Bone. Smoke forecasts as well as A.A. Meteors were supplied to both Army and Navy authorities in those areas.

On 22 December the meteorological section of H.Q. V Corps landed at Bone and on the 29th moved to Main Corps H.Q. between Souk el Arba and Souk el Khemis. This section operated on a fully mobile basis ; the forecast office was a 3-ton lorry and a W/T van housed the communications facilities. It took over responsibility for forecasting for the Division and Brigade Headquarters and for advising the meteorological unit with No. 5 Survey Regiment, thus relieving the First Army meteorological unit of much work and, incidentally, lessening the load on army signals.

Early in February, Army H.Q. moved forward to Laverdure and, owing to lengthening communications, shed all its commitments west of Bone. At this time a stationary rain belt lying along the mountains and missing the sparse network of reporting stations made forecasting difficult for several days. With the repulse of Rommel, First Army H.Q. moved on 12 March to a point south of Souk el Arba and the meteorological section pitched camp on a low

escarpment overlooking the valley of the river Mellegue. The section then took over the meteorological requirements of No. 242 Group (whose own meteorological section was temporarily disbanded) and became more than usually busy owing to the demands of the Wings.

With the First Army, formations known as Army Groups Royal Artillery (A.G.R.A.) had been created in the field for the first time and special arrangements had to be made to supply wind and temperature corrections to them.

At Robaa, No. 1 A.G.R.A. was controlling the British Artillery in support of the French XIX Corps, holding the Ousselta Valley sector. Their guns were firing over and around the Djebel Borgou, which rose to 4,500 feet, and the Meteor corrections issued from Army H.Q. were therefore of limited use. A meteorological detachment was sent to investigate the problem on the spot and supply corrections. No. 2 A.G.R.A. were deployed to the North near El Aroussa and they also were helped.

H.Q. IX Corps arrived with their meteorological section early in March and, after concentrating at Le Kef, moved to El Aroussa where the section took over the duties of advising Nos. 1 and 2 A.G.R.A.

H.Q. V Corps, with its meteorological section, had moved to Thibar at the end of February and had been involved in a flare-up as the enemy pushed along the coastal road from Mateur through Sejenane ; at the same time a more limited offensive to the South of Testour engulfed part of the meteorological section of 5th Survey Regiment ; much equipment had to be abandoned. For the counter-offensive to recover the territory east of the Beja-Djebel Abiod road an Artillery Group was formed and a meteorological detachment was provided from H.Q. V Corps. The country was very rugged and the firing levels of the guns varied, making the supply of accurate Meteor reports difficult.

In the operations to link up with the Eighth Army, H.Q. IX Corps moved often and their meteorological section kept up a high level of efficiency during periods of mobility.

Cap Serrat was cleared about this time and a meteorological detachment was sent there from Army H.Q. to take observations from the headland and pass them back by W/T.

Army H.Q. moved to Thibar in mid-April and H.Q. V Corps to Oued Zarga. This was a particularly busy time for the Survey Regiments whose meteorological sections operated in two elements, often at considerable distances apart, but their work in this area of uneven terrain was particularly valuable.

On 7 May the battle reached a climax and was soon over. A detachment from the meteorological section of V Corps reached Bizerta on 9 May ; Army H.Q. and H.Q. V Corps moved to Carthage and H.Q. IX Corps to Hamman Lif. The demands on meteorological sections diminished and those with First Army H.Q. and H.Q. IX Corps were withdrawn while the section with H.Q. V Corps moved back to Constantine to prepare for the next campaign. The meteorological sections with Survey Regiments remained with them.

Other formations.—No. 242 Group controlled the Fighter Wings which operated in close support of the Army. In the early days the group Headquarters was provided with a meteorological section but in March 1943, when H.Q. First Army moved to Souk el Arba to be alongside H.Q. No. 242 Group,

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the section was disbanded and the meteorological unit with First Army was detailed to serve both Headquarters. Two fighter wings based on Souk el Khemis (at first on Souk el Arba) were served by one small meteorological unit which maintained a full observing routine, including pilot balloon ascents, and issued to squadrons the forecasts received from the meteorological section of H.Q. First Army.

The Tactical Bomber Force formed as a result of the integration of all Air Forces in the theatre in February 1943, was provided with a Type I Meteorological Unit and H.Q. No. 232 Wing was served by a small Type 2. This force which engaged in close bombing support of the Army as well as night bombing of ports in Tunisia, raised varied meteorological problems. The most difficult conditions to forecast were the cloud cover over the Tunisian coast and the formation of radiation fog at the bases towards dawn when the bombers were returning from night sorties. An aerial survey showed that winds from a certain direction passed over a lake where the air acquired sufficient moisture to make all the difference between fog and moderate visibility as further cooling occurred.

The French in North-West Africa

The outline meteorological plan for operation Torch envisaged that any French meteorological station in areas which came under the control of the British Forces would be incorporated in the network of British reporting stations. Such an arrangement would have had to be piecemeal and it was doubtful whether communications would allow it to work efficiently. Fortunately the quick progress of events leading to the French throwing in their lot with the Allies enabled the Chief Meteorological Officer to open negotiations at a high level for the complete co-operation of the French Meteorological Service in North-West Africa.

Throughout Algeria, Tunisia and Morocco the French had a good network of reporting stations which sent in their observations to regional headquarters in Tunis (Tebessa after the German landings in Tunis), Algiers and Casablanca. All the reports were then assembled at Algiers. Communication was by public telephone and this arrangement was allowed to continue. The whole resources of the French Meteorological Service were placed at the disposal of the Allies and the good coverage of reporting stations materially helped the forecasting for operations.

The French broadcasting station FOG which was used for the transmission of collectives and analyses was placed under the control of the C.Met.O. Broadcasts were resumed, using British cyphers, and North-West African reports then became available to the Allies over a wide area. The equipment of the station was, however, out of date and in poor condition and a British broadcasting station (90G) had to be opened to ensure good reception in all areas.

The co-operation of the French throughout the Mediterranean campaign was complete and willing. They readily adopted new observation procedures and, where desirable, increased the reporting routine at important stations. On their part, both the British and the U.S.A.A.F. supplied equipment to the French to enable them to improve their efficiency and, in the case of the radio-sonde stations at Blida and Rabat, to continue in operation.

N.A.T.A.F. in Sicily

At the end of the Tunisian campaign, H.Q. Eighteenth Army Group dissolved and re-formed at Algiers as H.Q. Fifteenth Army Group in readiness for the Sicilian Campaign where the American Seventh and the British Eighth Armies were to deploy. The new Army Group H.Q. moved to La Marsa before the landing and was there joined by an advanced echelon of T.A.F., H.Q. A meteorological unit was required at La Marsa and was provided by transferring *en bloc* the unit with H.Q. First Army which was in process of dispersing. The unit joined Fifteenth Army Group on 25 June 1943.

From then until 10 July, when the landings in Sicily took place, the work of the meteorological section of H.Q. Fifteenth Army Group consisted of providing forecasts to Operations and Intelligence and continuing the Meteor reports to Tunis and Bizerta. The main forecasting for the operation was, however, carried out at Malta where an advanced H.Q. of Fifteenth Army Group moved just before D Day. The meteorological section at Army Group did not, therefore come into the battle picture until they arrived at Syracuse on 2 August.

On 28 June 1943 a small meteorological unit was detached from V Corps and attached to 'G' Force H.A. at Sousse. From there it went with 51st Highland Division to land near Cape Passero on D plus 1. Within three hours of landing, the first Meteor report was issued. During the actions in front of the airfields at Gerbini the unit joined the H.Q. of 57th Regiment, R.A., at Catania. The W/T van and much of the meteorological equipment were wrecked by shell-fire but the unit suffered no casualties. Later it was attached to No. 1 M.O.R.U. (Mobile Operations Room Unit) and then to A.A. Brigade H.Q. at Syracuse to provide A.A. Meteors and smokescreen forecasts. These duties were taken over by the meteorological section of H.Q. Fifteenth Army Group on 4 August and the small section at Syracuse rested until it was called up to move to Catania to join H.Q. No. 335 Wing.

Towards the end of August, H.Q. N.A.T.A.F. moved to Cassibile with its meteorological section which was then able to assume the role being filled by the meteorological section of H.Q. Fifteenth Army Group. The latter was, therefore, disbanded on 3 September and many of the personnel were used to form a meteorological unit for a G.R. Wing at Borizzo in the West of Sicily.

In Sicily contact was made with meteorological units which had operated from Egypt with the Eighth Army. No. 12 Meteorological Forecast Unit was attached to H.Q. Desert Air Force; it left Malta for Sicily on 16 July and landed at Syracuse on the following day, whence it moved on to Lentini. No. 125 Mobile Meteorological Unit went to Sicily with the assault convoy and some of the personnel with the W/T van landed at Marzaniari in S.E. Sicily. The unit joined the 165th Field Regiment R.A., a gun regiment of 25 pounders and later joined the 4th Survey Regiment and worked with No. 5 A.G.R.A. until Messina fell. No. 126 Mobile Meteorological Unit landed at Padrino also with the assault forces. The unit was attached at different times to several medium regiments R.A. under the control of No. 6 A.G.R.A.

When No. 12 Meteorological Unit arrived at Lentini it soon established contact with Nos. 125 and 126 Mobile Meteorological Units. Reports and forecasts were exchanged and small collectives broadcast from the parent unit. These were intercepted by Malta and passed on to others interested.

Eventually however, there were enough meteorological units in Sicily to justify special arrangements for the collection and broadcast of basic reports. Accordingly, the meteorological section of H.Q. N.A.T.A.F. was provided with a transmitter; all units reported, directly or indirectly to H.Q. N.A.T.A.F. and then listened to the collective broadcasts which also included battle area forecasts of all weather elements. All meteorological units were then able to know the advice being given to Operations Headquarters and co-ordination was thus achieved. The broadcasts were also received by the Central Forecast Section and retransmitted.

Two other meteorological units which played a part in the Sicily campaign were those attached to H.Q. T.B.F. and H.Q. No. 232 Bomber Wing. These units moved in from Africa when the capture of airfields south of Catania had been consolidated and provided forecasts in Sicily during the closing days.

During the period from the formation of N.A.T.A.F. until the end of the Sicilian Campaign much thought was given to the type of meteorological service required by a composite army–air force organisation. Meteorological units which came out to North-west Africa with First Army were completely mobile and carried their own communications. On the other hand, the meteorological sections of R.A.F. formations did not at first possess their own transport, but were self-contained in regard to wireless equipment and personnel. It soon became clear that all meteorological units, whether attached to the Army or to the R.A.F., must be independently mobile and must be linked together by a system of 2-way communications. In fact mobility and wireless were the main problems in evolving a meteorological organisation within N.A.T.A.F.

By the time of the Sicily campaign every unit was mobile and each had introduced various refinements into its mobility. For example each unit converted its 3-ton lorry into an office so that the delay in functioning after a move was reduced to a minimum. The communication system that was developed was based on a main collecting centre at H.Q. N.A.T.A.F. and a subsidiary collecting centre at No. 12 Meteorological Unit attached to H.Q. Desert Air Force. The latter collected on special wavelengths the weather reports from all meteorological units in the Eighth Army–D.A.F. area and passed them on to the meteorological section of H.Q. N.A.T.A.F. which also collected reports from the units in the remainder of the area. Finally, every three hours, when all reports had been gathered at H.Q. N.A.T.A.F., a complete message was broadcast for interception by all units. Without these reports accurate forecasting, especially of close support operations, would have been impracticable.

N.A.C.A.F. in North-West Africa and Sicily

North African Coastal Air Force was formed in February 1943 as a component of North-west African Air Forces and became responsible for the coastal defence of North African and for all reconnaissance operations in the Western Mediterranean. N.A.C.A.F. forces were intensively employed in the operations in Sicily and Italy. The operational area covered by N.A.C.A.F. was large and the squadrons were located at widely separated airfields. There was not enough meteorological personnel available for all these various units so that some of them had no direct access to meteorological information or advice. Each such unit had to be served by arranging for the supply of information

from the nearest meteorological unit using all available communications; in these cases, of course, no personal briefings were possible. The organisation of the meteorological sections of N.A.C.A.F. units was based on the policy that the best advice should be available at the highest formation.

A Type 1 meteorological unit had been formed at H.Q. N.A.C.A.F. in Algiers during March. Type 2/3 units were also attached to the R.A.F. Stations at Tafaraoui, Blida and Bone. A Type 2 unit was attached to Headquarters No. 328 (G.R.) Wing stationed at Protville (between Bizerta and Tunis), whilst a Type 4 unit was attached to Headquarters No. 323 Wing at La Sebala (near Tunis). In June, Headquarters No. 242 Group came under the control of N.A.C.A.F. and it became necessary to re-form the meteorological section of this H.Q. (now stationed in Bizerta). Accordingly a Type 1 unit was formed at H.Q. No. 242 Group during the second half of June. In addition, to meet the needs of R.A.F. units using the airfield on Lampedusa, a Type 2 unit was formed there towards the end of June.

The Type 1 at H.Q. N.A.C.A.F. in Algiers was responsible for the meteorological supervision of all the other units and the Type 1 at H.Q. No. 242 Group in Bizerta was responsible to H.Q. N.A.C.A.F. for the control of the meteorological units in Tunisia and on Lampedusa. The distance between Algiers and Bizerta and to the limited communications available, made it impossible to co-ordinate fully the meteorological information supplied by the two Type 1 units, but both received the general advice broadcast by the Central Forecast Section and in applying this to the problems of Coastal Air Force exercised their judgment separately.

Towards the end of July the meteorological units attached to H.Q. No. 323 Wing was withdrawn and arrangements were completed for the requirements of that Wing to be supplied by the unit at H.Q. No. 329 Wing. Meteorological units in Lampedusa were also gradually withdrawn.

In early September a meteorological unit was attached to H.Q. No. 325 (G.R.) Wing stationed at Borizzo. Also, at the end of the Sicilian Campaign a meteorological unit was formed at Syracuse; in October it moved to Catania where it was attached to H.Q. No. 335 (Fighter) Wing and later it became responsible for the supply of information to the Staging Post of Ferry Control set up there.

During October several changes resulted from the landings in Italy. A meteorological unit was formed early in the month and attached to H.Q. No. 287 (Fighter) Wing which had become responsible for the Bizerta Fighter Sector. H.Q. No. 242 Group with its meteorological section left Bizerta for Taranto in the middle of October and H.Q. N.A.C.A.F. set up a Command Post in Naples. Most of the Type 1 units at Algiers thus had to be sent to Naples to provide meteorological services for N.A.C.A.F. units in Italy.

The N.A.C.A.F. meteorological units had to supply information and advice of a very varied nature. In addition to the requirements of the R.A.F. they had to cover various other commitments. Most of the units were stationed near the various North African ports, so that forecasts were required by Naval Units, Balloon Barrage Squadrons, Smoke Screen and Anti-Aircraft companies.

The meteorological section of H.Q. N.A.C.A.F. gave advice to both Naval and Air Force Staff and the Senior Meteorological Officer was also responsible for liaison with the French Meteorological Service in Algiers. The advice

needed by the R.A.F. included forecasts for day and night fighters, anti-shipping patrols and anti-submarine attacks; also for the protection of day and night convoys.

At the G.R. Wings, 24-hour relays of reconnaissance flights were maintained and much personal briefing of aircrews was required. The forecasts issued for these flights covered the whole Western Mediterranean up to the South of France and the Gulf of Genoa and were often required for periods of more than 12 hours.

There was considerable work of a special nature. For example, the meteorological unit at Blida was required to supply forecasts for the return flights of the 'shuttle-bombing' aircraft from the United Kingdom. Forecasts were often required by aircrew, both British and American, of transport squadrons and in some cases these forecasts became a routine matter.

Before the landings in Sicily, the activities of N.A.C.A.F. were intensified and, in particular, the meteorological section of No. 242 Group was fully employed in connection with the protection of convoys and offensive strikes against enemy shipping and submarines. During this period Naval Headquarters moved to Bizerta and the Naval Staff Meteorological Officer worked closely with the meteorological section of No. 242 Group.

After the occupation of Sicily, the invasion of Italy maintained the demand for meteorological advice; forecasts were required for aircraft escorting an increased number of convoys and for reconnaissance aircraft operating over an extended area.

N.A.S.A.F. in North-West Africa

The Strategic Air Force was largely an American organisation and its weather requirements were mostly supplied by 12th Weather Squadron. No. 205(R.A.F.) Group was under the Strategic Air Force and was in effect the night bomber component. It had a Type 1 meteorological unit at Headquarters and one of the Wings, No. 330, had a Type 3 unit. As the various Wings were close together on airfields round Kairouan, these two units could supply forecasts to them all and undertake personal briefings before operations.

One of the meteorological features of the night bomber operations from Tunisia was that, as the enemy fell back, the distance from worth-while targets increased and finally the bombers were operating at a very long range. It was all the more important, therefore, for the forecasts of conditions at target to be accurate and for aircraft not to have to fly around awaiting a clearance. It was also vital that wind forecasts should be free from large errors, whether in speed or direction, so that navigators could correctly estimate their range.

North-West Africa, Sicily and Sardinia

After the campaign in Sicily ended, arrangements, begun long before, were completed for the transfer to Italy of a number of meteorological units, most of them in the N.A.T.A.F. organisation. It was also necessary to complete the establishment of a number of units which would remain in North-West Africa and Sicily or, later, move into Sardinia. The role of these units, though static and routine, was extremely important. The units based in North-West Africa, Sicily and Sardinia had mostly two separate functions: to serve units of Coastal Air Force and to serve units of Transport Command which were engaged in reinforcement as well as normal transport duties. Meteorological

units with responsibilities to both Commands were located at Maison Blanche, Blida, Bone, Setif, Tafaraoui (near Oran) and Protville (near Tunis) and Sardinia. Units at Ras el Ma, Oujda and Biskra were concerned solely with Transport Command requirements.

A feature of the preparation for entering Italy was the broadening of the British meteorological organisation to include South African, Canadian and Polish Units. Some S.A.A.F. meteorological units had been with Desert Air Force and Eighth Army right through from El Alamein into Sicily and by the autumn of 1943 their numbers were beginning to increase. Thus a number of forecasting and observing units were added to the British network, and the two services added to each other's efficiency. The S.A.A.F. organisation also helped the British in the loan of personnel. Staff who could be spared from S.A.A.F. units were attached to R.A.F. units and helped to relieve the acute shortage of personnel. Canadian meteorological units arrived in the Mediterranean theatre with the Canadian Corps which took part in the Sicily landings. These units had trained in England and had worked with British units organised on similar lines.

Polish meteorological sections had been formed with the Polish Corps in the Middle East which it was intended to operate with the Polish forces in Italy; these sections were to be under the technical and administrative control of the R.A.F. meteorological organisation.

The surrender of Italy and the withdrawal of the Germans from the foot of that country as well as from Sardinia left an appreciable part of the Italian meteorological organisation intact. It was important therefore to keep it in being to serve the Allies. In September the Chief Meteorological Officer flew to Brindisi to contact the Head of the Italian Meteorological Organisation for South Italy. His service was quickly put under R.A.F. direction and the Italian reports were broadcast from Brindisi in special British cyphers. A British meteorological officer remained as Liaison Officer to the Italian meteorological service and ensured that proper security was observed. Similar arrangements were made for the Italian meteorological service in Sardinia.

M.A.T.A.F. in Italy

The meteorological section of H.Q. M.A.T.A.F. (previously N.A.T.A.F.) landed at Taranto on 1 October 1943 and moved to San Spinto, a few miles north of Bari. It was the first full forecast unit set up by the British in Italy and requests for weather data poured in from all kinds of Navy, Army and R.A.F. units. As in past campaigns, main lines of communication radiated from T.A.F. and Army Group H.Q., and the unit met its various commitments without undue difficulty.

At this time a large amount of work had to be done for transport aircraft. Bari Airport became the terminal for routes to Cairo, Castel Benito, Tunis, Algiers, etc., and daily briefings at the airport were provided. Forecasting was not easy during this season. Flights across the Apennines to Naples were hazardous and the question of getting aircraft through the winding passes when the surrounding mountains were enveloped in cloud was constantly arising.

The Navy were keenly interested in the strength of the wind and the state of the sea. There were many small service craft in use and it was often safer, if weather conditions permitted, to disperse these outside the harbour walls than

to keep them in congested docks where they presented a collective target and also occupied valuable docking space. In addition, disabled ships were towed to a port where necessary repairs could be effected; only when the forecast of the strength of wind and state of sea was below fixed limits would work such as this be attempted.

There was also the work of transport aircraft requiring pinpoint briefing for their individual tasks; visibility of signals from the ground and the effect of wind on the parachuting of supplies had to be allowed for, as well as favourable route and base conditions, since many of these sorties were carried out at night; often the places chosen were particularly inaccessible spots in the mountains of Italy and the Balkans.

In the early days of the Italian campaign arrangements were made for some of the isolated Allied elements within enemy-controlled areas to include brief weather reports with their communications to the Special Forces Section. These reports were passed to M.A.T.A.F. by Special Forces Intelligence and provided some data from areas which would otherwise have been almost blank on the charts. The reports were not made by trained weather observers and had to be evaluated accordingly; they were also spasmodic but were better than no reports at all.

While this work was in progress other meteorological units were moving into Italy—American, Canadian, South African, Polish, British. Most of these were part of the Army-Tactical organisation, and from them was built a network of reporting units.

Weather reports in the battle area were collected and distributed in cypher. At first this was done by issuing each reporting unit in the network with its own cypher pad, a corresponding copy being at the receiving end. To make all these weather messages available to each of the units involved encyphering and decyphering in two different codes with a consequent delay and loss in value. The use of a common cypher for the collection of weather reports by point-to-point W/T was therefore decided upon towards the end of 1943. All holders could then listen in on an individual collection and decode for themselves without having to wait for the rebroadcast of a complete collective in a second code. This did not obviate the necessity for the second broadcast by the M.A.T.A.F. Meteorological Section, undertaken as it was for the benefit of a much larger circle, but it did make the vital front line data immediately available to all those directly interested. As practically all incoming information arrived in cypher and had to be decyphered before it could be used in plotting charts and making weather decisions, and as much of it had to be re-cyphered before distribution, a large amount of time and energy was expended on this side of the work. While this was going on the information was becoming older and of less value. A balance had therefore to be struck whereby security was maintained with a minimum of delay in transmission.

Towards the end of January 1944, the part played by M.A.T.A.F. meteorological section in co-ordinating the supply of meteorological information and briefings for a combined land, sea and air effort was shown when preparations were being made for Operation Shingle, *i.e.*, the Anzio landings. On the meteorological side it involved the separate briefing of the Chiefs of Staff, etc., of the Navy, Coastal Air Forces, Strategic Air Force and of the combined Tactical Air Force and Allied Armies by their own meteorological sections.

The initial stages of the operation were controlled from two main centres, Navy House in Naples and the Army-Tactical H.Q. at Caserta. In such cases it was not enough for the separate headquarters to know the general position; the finer details and weather outlook had to be agreed upon so that the dovetailing of operations requiring an emphasis on different aspects of weather should be successfully carried through. After the initial landings four days of operational weather were required to consolidate the position enough to give the operation a reasonable chance of success. Meteorological advice was co-ordinated by the M.A.T.A.F. Meteorological Section. The operation worked according to plan and the weather did not deteriorate until the evening of the fourth day when rain set in.

Operations such as 'Operation Mallory,' when various targets from the Brenner Pass down on to the Plain of Lombardy were given to the six groups of the Tactical Medium Bomber Force, were a constant test of the forecasters' skill since the formations needed to see their target from 8,000 feet and the timing of operations was an important factor in their success. Abortive sorties were not only a direct advantage to the enemy but a waste of operational effort.

The bombing of Cassino on 15 March 1944 was another example of a combined effort in which the 'heavies' of the Strategic Air Force and the 'mediums' of the Tactical flew in over the target in waves and were then followed by an assault from ground troops. Failure on the weather side might have meant not merely an absence of any gain by the Army but an actual loss of valuable ground which it had taken many months to capture. What were the meteorological requirements? From the Army point of view the absence of heavy rain was desirable; aircraft bases and target area had to be clear of fog at dawn; there had to be no cloud below 10,000 feet over the target for 'mediums' or below 18,000 feet for the 'heavies'; and finally for the rest of the day, *i.e.*, midday onwards, there had to be less than 4/10 of low cloud for the close support of ground movement from the air. Throughout the operation vertical and horizontal visibility had to be good. In the actual action these conditions were fulfilled with a narrow margin, as at that time an upper front moved slowly south-east towards the target area giving first high and then medium cloud and on the following morning some slight rain.

The mountainous nature of the Italian mainland with its considerable density of artillery of all kinds along this front produced a number of 'wind' problems for the M.A.T.A.F. meteorological section. Long range artillery and anti-aircraft guns were used in high elevation against surface targets. This type of fire meant that projectiles reading up to 30,000 feet were often 'lobbed' over mountainous obstacles rising to 4,000 or 5,000 feet or even more. Correction by flash spotting on the target was thus often impossible and meteor corrections had to be relied upon. In order to improve the information available for preparing such meteor corrections it was decided to use radar aids for obtaining wind directions and speeds. Four radar wind units were formed in Corps areas along the length of the front. All were working by the autumn of 1944, when two further R.A.F. radar units were brought into commission.

Meteor corrections for guns in the field were supplied as follows. Mobile meteorological units carried out pilot balloon ascents and prepared meteor reports with the aid of the data they obtained. Radar wind units contributed wind figures to an average height above 30,000 feet. Upper air temperatures

and humidities were supplied by the M.A.T.A.F. Meteorological Flight. These winds and temperatures were received by phone or through M.A.T.A.F. meteorological W/T network and then rebroadcast by the latter for general use along with forecasts of winds, temperatures and weather for the front. Thus, incoming upper air data were concentrated at a point where they could be analysed and from which they could be distributed.

Desert Air Force

Entry into Italy : For the landings on the mainland of Italy No. 12 Meteorological Unit split into two parts. The first party embarked at Catania on the night of 18–19 September and landed at Crotone in the Gulf of Taranto on the 20th. The second party came by road via Messina and across the hills of the toe of Southern Italy. For a short while the unit moved to Montevino, in the hills to the west of Bari ; another move was made to a camp near Lucera, to the north of Foggia, on 8 October.

No. 126 Mobile Meteorological Unit played an important role when it was decided to use the fighter wings of D.A.F. as advanced artillery in the hills. As mornings were usually clear and cumulus developed during the day, estimated times were required for the 6/10 cloud cover which was the maximum under which the aircraft could operate. Up-to-the-minute local reports were, therefore, essential. No. 126 Mobile Meteorological Unit supplied these data over the W/T link every hour until the cloud coverage was too great for the aircraft to operate.

At this stage V Corps went into the line and No. 125 Mobile Meteorological Unit travelled from Messina and were put under the control of the forecasting unit which had already been attached to this Corps H.Q., from North-West Africa. Advisory forecasts were supplied by No. 12 Meteorological Unit.

After the crossing of the Sangro (which was postponed for 48 hours because of forecasts of heavy rain) Advanced H.Q., D.A.F. moved forward to Vasto with Main H.Q. Eighth Army on 7 December but No. 12 Meteorological Unit remained with Rear H.Q. D.A.F., and moved to San Severo on the same date. The positions were now more static with the full onslaught of winter in the hills and the holding of the armies on the west coast to the south of Cassino. No. 12 Meteorological Unit was in an unusual and unsatisfactory position. No personal talks or advice could be given to Army or Air Force staffs and all forecasts were sent by R.A.F. teleprinter link from San Severo to Vasto. Weather was forecast without any idea of what Army or Air Force intentions were. Repeated requests were made to join the H.Q. at Vasto but no accommodation could be arranged and the unit stayed at San Severo through a severe winter in a tented camp until 17 March when it moved to Vasto.

At this time, No. 127 Mobile Meteorological Unit, which had landed near Salerna with X Corps, was to the west of the Apennines near Cassino ; No. 126, under XIII Corps, was in the east centre and No. 125 was on the coast. This distribution across the country was dictated by Army artillery requirements but was also the most satisfactory from the meteorological standpoint as it gave an excellent network of reports from the Italian front.

As No. 12 Meteorological Unit moved forward, a small advance party was sent ahead to set up a combined forecasting and W/T section in a tent while the main rear party were on the road. In this way the unit was always

completely operational as regards issuing forecasts. None of the four main synoptic charts ever failed to be plotted from the day of the landings in Sicily. Transmissions could be made within half an hour of the departure and arrival of the W/T vehicle so it was always timed to move off immediately after a routine transmission.

In May, when fighting flared up again, all the mobile units were in the line and very busy. Following the capture of Cassino and the advance to Rome, No. 12 Meteorological Unit moved across the Apennines on 4 June to Castroxielo, and then immediately with A.H.Q., D.A.F., to Valmontone just south of Rome. The next move of No. 12 Meteorological Unit with H.Q., D.A.F., was to the southern bank of Lake Trasimeno on 1 July, where a pause occurred. H.Q. R.A., X Corps switched No. 127 Mobile Meteorological Unit from 6 A.G.R.A. for 24 hours for a calibration shoot.

On 23 July H.Q., D.A.F., moved forwards to Montericcione a little north-west of Siena. At this time the American Fifth Army were confined to a comparatively short length of the front, on account of the withdrawal of certain troops for the invasion of Southern France, and D.A.F. were now responsible for tactical air support along the whole front in Italy. This increased the work of No. 12 Meteorological Unit. Following the liberation of Florence the Main Eighth Army and A.H.Q., D.A.F., switched over to the east coast. Consequently No. 12 Meteorological Unit was divided, the one party remaining at Montericcione to carry on the normal point-to-point transmissions with the mobile meteorological units and H.Q., M.A.T.A.F., and the other moving with a section of H.Q., D.A.F., on 24 August back to Foligno and over the Apennines to Jesi where it continued to supply the meteorological advice required by Air Staff. The Canadian Corps, now back in the line, had a meteorological unit under a meteorological officer at V Corps. H.Q., Nos. 232 and 244 Wings, with their meteorological sections were at Perugia.

On 22 September H.Q., D.A.F., moved to the vicinity of Cattolica between Pesaro and Rimini ; the latter town was occupied by the Army a week later. At this time there was a major outbreak of cold air from the north and violent thunderstorms. The thundery rain persisted and paralysed movement on the battle front. After two days the rain became intermittent and then ceased ; the battle moved forward a little but the small rivers were now torrents ; Bailey bridges were swept away. Daily meteorological conferences were begun with the Eighth Army Commander and continued until the end of the campaign. For the next two or three months the Army Commander was anxious to make the utmost use of any break of three days in the unsettled autumn weather. This requirement presented the forecasters with a serious problem especially in such an unsettled season of the year ; if the forecast of three fair days failed it might mean that advanced troops would be cut off by rising rivers behind them.

The rain then began again and was so heavy that the position of Army and D.A.F. H.Q.s in the field became untenable and they hastily moved into buildings in Cattolica on 11 October. Later, the H.Q.s moved into buildings at Rimini. The bad weather continued and the flooding was serious. No. 125 Mobile Meteorological Unit with 1 A.G.R.A. were now at Forlimpopuli but No. 127 had remained back with 6 A.G.R.A. as X Corps were out of the line. No. 126 Mobile Meteorological Unit was a little farther from Florence in the

upper valley of the River Santurno. On 22 November No. 12 Meteorological Unit moved with H.Q., D.A.F., to Cesena, and apart from the push in the east leading to the liberation of Ravenna the front became quiet for the winter. Research was opened at the Fifteenth Army Group—M.A.T.A.F. level on soil trafficability for the spring offensive. The meteorological aspect of the investigation was examined by the S.Met.O. at M.A.T.A.F. and the officer concerned on the Army side was put in contact with the Meteorological Officers at V Corps and Polish Corps who made observations on his behalf on the water content of the immediate subsoil.

Early in January 1945, No. 125 Mobile Meteorological Unit were at Faenza with 1 A.G.R.A. who were about to move out of the line so it was decided to send the unit to M.O.R.U. on the coast at Bellaria as weather observations from a place on the coast were lacking at that time; the unit remained with M.O.R.U. until late in February. Meanwhile No. 127 Mobile Meteorological Unit were attached to a heavy regiment R.A. in support of Polish Corps to the south-west of Faenza.

The measurement of upper winds by radar was then tackled in earnest. Two radar sets were supplied to the Chief Meteorological Officer, M.A.A.F., to use on the Italian front and he assigned one to a meteorological section of M.A.T.A.F. (Florence) and the other to No. 12 Meteorological Unit, D.A.F. The radar personnel and set for No. 12 Meteorological Unit arrived at the end of January. As the set had arrived straight from the United Kingdom it was of a later mark number than any other set used for A.A. work in Italy; the filaments heated in a fraction of the time taken in the old marks. The Brigadier of 12th A.A. Brigade told S.A.S.O. of D.A.F. that such a set would be of much greater value to him than for meteorological purposes for which a few minutes longer to heat the filaments were of no consequence. It was therefore arranged to exchange it temporarily with one of the radar sets of 12th A.A. Brigade. The other set arrived damaged and was not made serviceable until March when it was set up at Ravenna where the personnel were attached to No. 7 S.A.A.F. Wing. The section was named the Eastern Radar Meteorological Unit. Later the personnel were attached to No. 324 Wing at the same location. Four ascents were made per day and, coupled with the other results received at No. 12 Meteorological Unit, made up a comprehensive picture of the wind structure. No. 253 Wing which, unlike other Wings, had no forecasting section of its own, had now switched over to night operations and required meteorological facilities on the spot. Also M.O.R.U. could only contact a forecaster by telephone. It was therefore decided to open a forecasting section at M.O.R.U. and in view of the proximity of No. 253 Wing it was arranged that an officer should go from M.O.R.U. every afternoon to brief crews of that Wing.

The offensive was planned to take place on 9 April. The enemy were to be attacked by the heavy bombers of Strategic Air Force on a narrow sector to the north of Faenza in the early afternoon and harried by all the available aircraft of D.A.F. for the remainder of the day. After dark the heavy bombers would again strike in the same sector and would require accurate information regarding upper winds. No. 127 Mobile Meteorological Unit was a little to the north-east of Faenza and was therefore given the task of making the necessary wind observations; facilities were made available for passing the data immediately to the appropriate control.

The final signal to go ahead was given after a conference in the early morning of the 9th when the forecaster was cross-questioned at length by the Army and D.A.F. Commanders. All went as planned, the enemy formation were broken up all along the line and the advance pressed.

On 20 April H.Q., D.A.F., moved to Imola; and on the 29th to San Nicolo. The forecast section was withdrawn from M.O.R.U. and the Eastern Radar Section were moved back to No. 253 Wing at Cesenatico. Nos. 125 and 126 Mobile Meteorological Units were already across the River Po. As X Corps were pulling out of the country and were to be provided with meteorological facilities in their new theatre of operation, No. 127 Mobile Meteorological Unit was intercepted near Ancona and instructed to proceed complete to join No. 12 Meteorological Unit.

Entry into Austria: An expedition by road into Austria by an advance party of D.A.F. was then decided upon and together with one-half of No. 12 Meteorological Unit the party set out for Klagenfurt. The other half of No. 12 Meteorological Unit stayed at Mestre for another week and then moved with H.Q., D.A.F., to a site some ten miles north-west of Udine where it remained. No. 126 Mobile Meteorological Unit moved into Trieste after the withdrawal of the Yugoslav forces to the Morgan Line, and V Corps with No. 125 Mobile Meteorological Unit moved into Austria as did No. 324 Wing, with its meteorological unit. M.O.R.U. with the former meteorological section of No. 232 Wing, moved to a spot some six miles south of Udine. All the remaining Wings were located on the various airfields between Udine and Treviso. Eastern Radar Section moved up with No. 253 Wing and was then attached to No. 244 Wing at Treviso.

Having arrived at Klagenfurt on 10 May, the S.Met.O., learned that there had been a major German meteorological unit near the town. This was found to be the meteorological collecting centre for Southern Austria complete with staff. It was decided that no meteorological units and staff in the then British occupied area should be allowed to disperse, and as soon as possible the S.Met.O., visited all such units to see that this decision was enforced and to restart in a modest way the collection of reports at Klagenfurt. The collective report was telephoned to No. 12 Meteorological Unit and its transmission back to M.A.T.A.F. was facilitated by the provision of a high power transmitter. A skeleton staff was installed in the old meteorological office at Klagenfurt to make full synoptic reports. For a time the forecasting section with H.Q., D.A.F., remained in the office vehicles on a hill above the airfield but when a Transport Command Staging Post arrived in June the forecasting section moved into the office at the airfield. About this time the S.Met.O., nominated as Officer i/c Austrian Meteorological Service, arrived and the running of this organisation was handed over to him.

Closing Stages: The setting-up of a Transport Command Staging Post at Campoformido (near Udine) led, at the beginning of August, to the transfer to that airfield of the meteorological section from M.O.R.U. All meteorological requirements at D.A.F. in Italy were then dealt with at Campoformido where D.A.F. Communications Flight was based. On 30 August the whole rear party of No. 12 Meteorological Unit moved up to Schwechat (Vienna) in order to form a full forecasting section there. A week later D.A.F. handed over all R.A.F. commitments in Austria to the newly formed H.Q., R.A.F. (Austria),

with the exception of No. 324 Wing at Zeltweg. The meteorological units at Klagenfurt and Vienna were therefore dissociated from No. 12 Meteorological Unit and the S.Met.O. with a small staff returned to D.A.F. H.Q. near Udine.

Apart from the small staff at H.Q., D.A.F., No. 12 Meteorological Unit had personnel at Campoformido airfield, at No. 125 Mobile Meteorological Unit, at Eastern Radar Detachment and with the former M.A.T.A.F. radar section then at Bologna ; No. 126 Mobile Meteorological Unit was disbanded.

At the beginning of October, A.H.Q., D.A.F., amalgamated with Rear H.Q., D.A.F., in the eastern outskirts of Udine, and M.O.R.U. was absorbed into the H.Q. The S.Met.O. and a small staff moved with the H.Q. The meteorological sections at 5th Survey Regiment at St. Michel in Austria and at 3rd Survey Regiment near Monfalcone were disbanded.

No. 12 Meteorological Unit continued to dwindle from then on as personnel proceeded on release and only a few replacements were forthcoming. The unit was disbanded in April 1946 after which forecasts were supplied to D.A.F. by signal from Pomigliano.

The Balkan Air Force

The Balkan Air Force (B.A.F.) was formed in June 1944, with its Headquarters at Bari in South-East Italy, and the C.Met.O., H.Q., M.A.A.F. arranged for a Type 1 Meteorological Unit to be established there. The main work of this unit was the briefing of the A.O.C., S.A.S.O. and Operations Officers. The Army and Navy Branches were also supplied with meteorological information as required. The area of operational activity necessitated a careful study of weather conditions over Italy and the whole of S.E. Europe with particular reference to Yugoslavia and the Balkan States and further afield to Poland and Czechoslavakia. Forecasts were supplied to units at Bari for flights to Belgrade, Sofia, Bucharest and later to the Athens area. These units included a Russian Squadron and the B.A.F. Communications Flight. A Russian Meteorological Liaison Officer was briefed daily for non-operational flights to Rumania and South-West Russia.

Forecasts and A.A. Meteors were encyphered and transmitted to the advanced base on Vis Island twice daily and routine area forecasts were prepared and delivered by hand to Allied Forces Sub-Commission at Bari.

Every effort was made to supplement the limited and often scanty reports available from the target areas ; contacts were made with the meteorological section of No. 205 Group in the Foggia area and with the P.R.U. meteorological unit at San Severo ; additional information was collected from other meteorological units farther north, including the T.A.F., D.A.F. and S.A.F. sections. Routine conferences were instituted with the meteorological offices at Brindisi and Biferno to discuss the main operational activities.

In order to be fully aware of all the diverse activities of the numerous missions, close touch was maintained with the various sections of the 37th Military Mission, a component of B.A.F. The reception of reports from the operational area was facilitated by connections with the Yugoslav partisans.

It was arranged, as soon as possible, for advance units in the zone of operations to prepare and send back weather reports. The first of these units was on Vis Island and observations were supplied by Yugoslav personnel, but later a British unit was moved in and pilot balloon ascents were made. Other reports,

usually very brief, were sent in from the increasing number of missions in enemy-occupied territory but the nature of their duties, which often necessitated rapid movement, made it impossible to arrange for a steady supply of these valuable reports. All messages considered to be of general interest were immediately passed to C.F.S. for inclusion in the M.A.A.F. broadcast.

Full reports were made by the meteorological units at Brindisi, Termoli, Zara and the units which later arrived in Greece. Some Yugoslavs trained in meteorology formed the nucleus of the Yugoslav meteorological network which came into operation soon after the Germans had been cleared out.

The main supply dropping operations were carried out by No. 334 Wing based at Brindisi. This Wing took supplies and personnel to the underground forces in the Balkan States, the targets normally being in Yugoslavia and North Italy. The forecasting facilities for these activities were provided by the meteorological unit at Brindisi.

In addition to the operational sorties by day and night, the Squadrons at Bari were engaged on transport duties throughout the Mediterranean to Algiers in the West and Cairo in the East. Forecasts for these flights were supplied from the Type 1 meteorological unit at H.Q., B.A.F.

Several squadrons were concentrated on the landing strips along the beaches near Termoli to harass the enemy supply lines and to attack selected targets in Yugoslavia, Albania and Greece. At first the forecasts for these sorties were supplied from H.Q., B.A.F., over telephone and teleprinter lines but owing to the difficulties of operating fighter aircraft at extreme range, the vagaries of the surface winds and other meteorological phenomena in this particular area and difficulties of maintaining regular communications, it was decided to establish a mobile meteorological unit to look after the requirements of these squadrons.

Entry into Yugoslavia : No. 56 Meteorological Forecast Unit was formed at Bari in March 1945, for duty with the squadrons which moved into the Zara area. This striking force was moved to the operational area in northern Yugoslavia. After a comparatively short but useful stay in Yugoslavia, the unit was transferred to the Milan Staging Post, on cessation of hostilities in Europe.

Entry into Greece : B.A.F. Units made landings by sea and air in Greece in October 1944. This involved moving considerable numbers of troops and supplies by air to the airfields in the Athens area to assist the Greeks in the final effort to clear out the enemy. To obtain direct information of the actual conditions in the landing area, a meteorological officer was successfully dropped by parachute at a spot near Eleusis. The reports thus obtained proved of great value in deciding the date and time for the operations.

For the parachute and glider invasion of Greece the weather was generally favourable but there was a strong surface wind and injuries to personnel and damage to supplies were sustained. This condition was not unforeseen but the intricate planning of the various combined efforts restricted the timing of the operation to a limited period.

No. 35 Meteorological Unit, composed of personnel from Middle East and Italy, was quickly established for duty with No. 337 Wing at Hassani airfield. Another meteorological unit was sent by air from Bari to provide information

for the newly established A.H.Q., Greece. This particular unit was captured, together with other A.H.Q. personnel, by E.A.M. irregulars and led away to the mountains. Some of the airmen suffered injuries and all suffered considerable hardships and privation before they were eventually relieved and repatriated.

A mobile reporting unit (No. 128) was set up at Salonika and another observing unit was organised at Crete. A little later, staff arrived from Middle East for reporting duties at Rhodes.

Operations in Southern France

Operation Dragoon, the landing in Southern France, was begun on 15 August 1944. It was largely a combined Franco-American affair and the British contribution consisted of fighter cover provided by three Wings of the Royal Air Force. The operation was mounted from Corsica and, taking account of the fine weather which prevailed at that time of the year, it was decided that the R.A.F. Fighter Wings should obtain their meteorological information from the U.S.A.A.F. weather organisation set up for the operation. No meteorological units of the R.A.F., therefore, took part.

French mobile forecasting and observing units formed part of the invading element contributed by France. These units were equipped with British vehicles and were assisted by the British Meteorological Service whenever negotiations had to be conducted to make up deficiencies in war establishment.

Co-operation with the U.S.A.A.F. and Free French

U.S.A.A.F. : Co-operation with the 12th Weather Squadron began with the planning of operation Torch and continued throughout the operations in the Mediterranean area. Initially the Meteorological Office was able to give considerable material help to the U.S.A.A.F. Weather Service and some 30 units formed in England were supplied with British observing and pilot balloon equipment; much of this was returned later when American equipment arrived in North-West Africa. In the final 18 months, considerable material help was given by the U.S.A.A.F. to the British Meteorological Service, the connection of British units to the American teletype network being perhaps the most important.

Technical collaboration, *e.g.* the interchange of analyses and forecasts was well developed and culminated in the formation of the combined Central Forecast Section at Bari.

At all times the 12th Weather Squadron worked in harmony with the British organisation and were always ready to place their resources at the disposal of the British Meteorological Service.

Forecasting Problems in North-West Africa and the Western Mediterranean

Apart from varying lack of data, both for the surface and the upper air, the main forecasting problems were the behaviour of fronts and depressions together with the assessment and prediction of their activity, and the determination of the effects of orography on cloud formation and upper winds.

Fronts and Depressions : The forecasters who first arrived in North Africa tended to apply too readily the frontal technique as developed from Norwegian methods and used in the United Kingdom. It was soon found that air-masses

may become appreciably modified in this area and that while the movement of fronts might be on a reduced scale compared with that in more northern latitudes, development at cold fronts might be appreciably greater and at warm fronts considerably less.

Most of the unsettled weather in this area occurs in the winter half-year and is associated with the invasion of cold air from the north. Whilst the arrival and movement of this cold air can be fairly easily detected, given an adequate network of surface and upper air observations, the effect of orography in producing waves on cold fronts and resulting secondary depressions as well as of increasing the precipitation and also the effect of warming and evaporation during the passage of cold, relatively dry air over a large inland sea such as the Mediterranean are difficult to assess in detail.

The depressions which form in the lee of the Atlas Mountains and their significance for sirocco development were studied at Meteorological Office Headquarters and the results were published in S.D.T.M. No. 43.

Outbreaks of thunderstorms are a regular feature of the intrusion of cold air into the Mediterranean area, especially in the early spring. Experience showed that the development of such storms is not necessarily due to heating below but may be due to the arrival of cold air aloft; this pointed to the need for an investigation of the causes of instability in the upper air. The forecasters also felt the need to investigate the causes and behaviours of desert depressions which form inland in Northern Africa and move from west to east. Sometimes these lows appear to have fronts, sometimes not, but they are generally preceded by the sirocco and are often associated with vigorous duststorms which may be a hazard to flying. Only empirical rules based on experience could be used for predicting the movement and development of these lows.

Effect of Orography : The influence of orography in producing lee depressions has already been mentioned but it also produces marked effects on air flow and the formation of cloud. For example, experience showed that in some areas, daylight operations would be limited to a short period between the dispersal of mists formed at night in the valleys and the growth of convection clouds during the day over the hills. The extent to which the obstruction of high ground affects the flow of air both at a distance from and above the mountains is known only in general terms, and further research is needed to improve the accuracy of forecasts of cloud amount and height and upper winds in hilly or mountainous country.

Very strong winds often blow along deep valleys. Examples of these are the mistral of Provence and the bora of Trieste. These ravine winds were the subject of a S.D.T.M. (No. 57) published by the Meteorological Office.

CHAPTER 22

GIBRALTAR AND MALTA

Gibraltar

The Treasury approved in September 1935, the establishment, as an emergency measure, of a temporary forecasting office in Gibraltar. Approval was given in 1937 for a permanent meteorological office with forecasting and administrative staff from the United Kingdom and full-time observers recruited locally.[1] Early in 1938, the observing duties were wholly taken over from the part-time staff who, at that time, were members of the staff of the Shore Signals Station. The services provided included forecasting facilities 13 hours a day. The meteorological office at Gibraltar was then a civilian organisation under the administrative control of the Overseas Branch of the Meteorological Office.

Liaison with the Navy was through the King's Harbourmaster and Captain of the Dockyard who acted as Naval Meteorological Liaison Officer and was responsible for the supply of confidential publications such as cyphers. Motor transport for conveyance of stores, etc., was provided from the Dockyard. Liaison with the Army was through various members of the General Staff of the Governor and Commander-in-Chief at Fortress H.Q. The Army were responsible for providing office accommodation. Liaison with the Local Government was through the Colonial Secretary. The Crown Surveyor and Engineer's Department performed various works services. As there was no R.A.F. unit in Gibraltar to act as 'parent unit', the meteorological office acted as a self-accounting unit.

The W/T section, which maintained two listening watches for the interception of various national broadcasts, collected the basic data which enabled three main synoptic charts to be drawn daily for 0700, 1300 and 1800 hours. covering the western Mediterranean and surrounding lands, North-West Europe and the eastern North Atlantic. Occasional upper air observations were made by aircraft of R.A.F. detachments stationed from time to time on the Rock.

Local observational data were broadcast regularly by the R.N. signal station. Forecasts, warnings and climatological information were supplied as required to the Services, civil authorities and local Press. In addition, for the benefit of H.M. ships, Fleet Synoptic messages were prepared thrice daily for broadcast by the Naval W/T station. These messages included a selection of data covering the Mediterranean and eastern North Atlantic and the neighbouring land areas ; the morning and evening messages included also forecasts for the sea areas. Shortly before the outbreak of war, a report was prepared on topographical factors affecting the forecasting of weather at Gibraltar.

[1] A.M. File S.41399.

The 'War Organisation of Meteorology in the Mediterranean', dated 28 September 1938, gave the following instructions for the routine to be introduced in the event of war in the Mediterranean :—[1]

(*a*) A 24-hour forecasting service to be introduced.

(*b*) Supply of weather information to the general public to cease.

(*c*) 'Fleet Synoptic' messages to be cyphered in the Confidential Meteorological Code.

(*d*) Broadcasting of synoptic reports to cease, and reports to be sent instead by cable to Meteorological Offices, London, and

(*e*) As regards receipt of information, arrangements to be made for reports to be sent by cable from France, French North Africa and Portugal (Lisbon).

The Head of M.O.5 had stated in a memorandum which he prepared before the war, that the introduction of a 24-hour forecast service at Gibraltar would necessitate the addition of one forecaster, one assistant and one W/T operator. He added that another forecaster and one more assistant would be required to meet the recommendation of a sub-committee of the R.A.F. Meteorological Policy Committee that a Type 3 office should be provided if and when a R.A.F. unit was stationed at Gibraltar. Other plans being considered at the outbreak of war were for the construction of a new meteorological office, on lower ground at the southern end of the Rock, and the erection of an additional anemometer for a special investigation at the extreme northern end of the Territory. Action was delayed, however, on both these projects.[2]

The supply of information to the local Press and radio-diffusion organisation ceased on 2 September 1939. From 0700, 3 September, a continuous watch was maintained. Forecasts were supplied to the Navy, Army, R.A.F. and Port authorities, and Meteor reports were supplied to artillery units. Synoptic reports were cabled to London and Malta. From 10 September, cabled synoptic reports for France and French North Africa were received from London, and from the 27th, a selection of British reports was also received by cable from London. The proposed service of cabled reports from Lisbon was not introduced as Portugal, Spain and Italy continued their national W/T meteorological broadcasts as in peace-time. Up to 22 October 1939, cabled reports were not being received from Morocco.

September 1939 to February 1942

Staff : During the first months of the war, difficulties arose in maintaining a civil organisation in an increasingly military zone. Those relating to the residence and movements of civilians were dealt with by negotiation with the various authorities. Difficulties in regard to local staff were due to competition for available manpower and the evacuation of the civilian population. It became almost impossible to replace local staff who resigned and the position became serious. At the end of July 1940, with only two W/T operators effective, the full W/T programme was not being maintained. It was not until late in 1940 that the retention of 'employed civilians' was authorised by a local Defence Regulation.

[1] A.M. File S.36435.

[2] A.M. File 726101/38.

Of the United Kingdom staff available in September 1939, one was nominally an administrative officer but had been given some experience of forecasting duties and could be regarded as a 'dependent' forecaster under training. In February 1940, a second 'dependent' forecaster arrived and continued under training. Despite the staff shortage, the 24-hour forecasting service was maintained with the officer-in-charge taking full roster duties. The two trainee forecasters became competent to forecast independently in September 1940. There were few other staff changes until reinforcements arrived in March 1942.

The R.A.F. authorities signalled Air Ministry in June 1941 on the question of increasing the meteorological staff in view of heavy delivery flight commitments. They also raised the question of moving the forecast section from Windmill Flats to the new H.Q. building which was situated in the new R.A.F. station which was being erected on reclaimed land in the area of the harbour and which became known as New Camp. The latter proposal raised difficult considerations as the available staff could not man two offices. No. 200 Group signalled Air Ministry again in July 1941, pointing out that the meteorological unit was the only one that had not been increased against the extra commitments ; the additional work involved in decyphering, which had increased very considerably, was encroaching to an undesirable extent on purely meteorological work. The staffing of the office was also affected by the growing sickness rate of the local staff, the annual total number of days lost through sickness having increased from one in 1938 to 59 in 1941.

Following complaints about the meteorological help which pilots had received, the Head of M.O.5 visited Gibraltar on 19–22 November 1941 and recommended that, apart from W/T staff, the establishment should be increased to 24. This recommendation was gradually implemented.

The period ended with the complete militarisation of the United Kingdom staff, notice being received from Air Ministry in February 1942 of their appointment to commissions in Class CC, R.A.F.O. A radical change had taken place at Gibraltar which was becoming increasingly a heavily armoured and closely guarded fortress, a short distance from which was a neutral or 'non-belligerent' and potentially hostile territory from which hundreds of workers passed daily. Security precautions were naturally elaborate and the movements of civilians were severely restricted, there being little distinction of nationality. Although the meteorological office, as a civilian organisation, had little or no official knowledge of defence plans, it soon became clear that militarisation was desirable if meteorological services were to be required in connection with such plans. There are advantages in having a civilian meteorological organisation to serve the needs of all three Services so long as the civilian organisation is largely self-supporting. In 'field' or 'fortress' conditions, however, the extent to which civilian staff become preoccupied with domestic matters may be a factor against technical efficiency and in extreme 'security' conditions such as prevailed in Gibraltar, militarisation of the forecasting staff at least seems to have been justified for maintaining full efficiency and full co-operation with the Services. The difficulty of maintaining the locally employed staff at suitable strength was undoubtedly increased by the fact that they were not militarised.

Relations with the Services : Liaison with the Royal Navy was maintained as before the war until February 1940 when the arrangement for supplying confidential meteorological codes was changed and the R.A.F. unit became the source for these publications. An increasing number of visits was made to the forecasting office by Navigating or Meteorological Officers from H.M. Ships. Numerous discussions took place on technical matters and arrangements were made for the supply of information in relation to particular requirements.

The observation site, which was held from the Army, was liable to be reclaimed for military purposes and was, in fact, reclaimed on 1 May 1940. An alternative observation site was chosen near the office, but before a decision was given on the plan for transferring the whole meteorological section to a new site or for temporarily re-erecting the anemometer on another site, the Army took possession on 18 May and dismantled the observation hut and anemometer. The anemometer was put in store and other instruments installed at or near the office ; as the former site had been chosen as the best available in the area, any new site was less suitable and was likely to be over-exposed as regards observations of rainfall.

At the beginning of September 1939, the R.A.F. contingent on the Rock consisted of a small detachment, with marine aircraft, from a unit based on Malta, but later in the month No. 200 Group R.A.F. was formed by a nucleus of staff from Malta and took up a H.Q. office in the Dockyard Tower, which housed the main R.N. administrative sections. Immediate liaison was established with the staff of No. 200 Group. It later became clear that none of the three Services regarded the meteorological section as a unit officially attached to it and it was decided that the section should be regarded as part of No. 200 Group so long as the latter remained at Gibraltar. The question of providing suitable accommodation for office and staff was thereupon taken up with No. 200 Group.

R.A.F. activity was increasing during the latter half of the period and the difficulty in maintaining liaison between meteorological and flying staff entailed by the distance between the offices became more evident. While there was no general requirement for personal briefing of aircrews, there were certain advantages in keeping all the meteorological work in a compact unit and a reasonably satisfactory service could be provided with limited staff, but from September 1941 there was an increasing need for briefing by a forecaster either at New Camp or at North Front. The time taken in travelling for briefing purposes increased rapidly until up to eight hours daily of the forecasters' time might be spent away from the meteorological office. The obvious solution was to move the forecasting section to the H.Q. building which became ready for occupation in the summer of 1941, but this building was apparently designed without any consideration of meteorological needs, as the offices later suggested for use as a forecast section were designed for photographic work and were soon occupied by a photographic section ; it was also impracticable to transfer the forecasting staff to New Camp without assistant staff. As the staff position improved in February 1942, it became practicable to maintain two offices and the main office was transferred to New Camp on 2 March 1942, leaving an observing section at Windmill Hill Flats. It was not possible until later to set up a section at North Front.

Collection of Data : Data continued to be received satisfactorily until Italy ceased to transmit meteorological data in plain code on her entry into the war. A scheme for transmitting data by W/T from Algiers, Tunis and Casablanca was tested early in June 1940, with little success so far as Gibraltar was concerned and reception of cabled messages of data for French North Africa ceased on 4 July. Some tests of W/T transmissions from Air Ministry were also made in June but this station was not heard after 25 June 1940. The situation as regards basic data was then very bad. In connection with certain forecasts required by naval units, attempts were made to receive the Malta Fleet Synoptic messages ; the W/T station cound not be heard and it was arranged for the data to be sent by cable. The first of these cabled messages was received on 31 July 1940.

It was arranged with the Naval authorities in April 1940 for vessels of the Boarding Service, which patrolled the Strait, to provide weather reports so that certain features of local weather, particularly variations of sea temperature, might be investigated.

Reception of W/T broadcasts from Spain, Portugal and Azores continued throughout the period. The reception programme was extended gradually to include most of the ' Home ' and ' Malta ' Fleet Synoptic messages, the resulting increase in cypher work being covered to some extent by the W/T in quiet periods. Additional data were received by cable from London, some of which, having a high degree of security, could not be fully used owing to lack of cypher staff.

A system was evolved for exchanging advisory forecasts between base stations, at first on a request basis for particular flights and later as a routine, the time of transmission and period of validity of forecasts being adjusted from time to time so as to cover peak periods of traffic on the main transit routes. By March 1941, data were being exchanged with meteorological offices at Malta, Bathurst and Gloucester. The messages were transmitted on R.A.F. W/T channels.

The synoptic reports of Malta were received by W/T broadcast from September 1940 ; broadcasts of data from Air Ministry were not available until later.

Supply of Data : During most of the first half of the period, Naval requirements were met by the Fleet Synoptic messages and by routine forecasts for local areas, the former being supplied thrice daily for broadcasting until February 1940 when the afternoon issue was discontinued. From March 1941, the Fleet Synoptic message was broadcast in two parts, one being a re-broadcast in plain code of the Spanish and Portuguese data and the other containing secret information in cypher such as analyses and forecasts.

The duplicated daily weather report, which was supplied to the Admiral-in-charge, was extended during 1941 to include the area Azores—Balearics—Southern England ; copies were supplied to H.M. Ships in harbour as required. In December 1941, the report was also supplied to the Staff Officer, Operations, R.N., and from February 1942 reports and forecasts for operational areas were supplied to the ' War Room ', Dockyard Tower. There were severe restrictions on civilians entering the ' War Room ' and the joint R.N.–R.A.F. staff made the display of weather information. Area Combined H.Q. was later developed, however, and a meteorological section was attached.

Special forecasts were required in July 1940 for the area Gibraltar to 5° E. in connection with Naval operations, and a series of special forecasts in connection with special operations was begun in August 1940, for periods of a few days, usually referring to the area Balearics—Sardinia—African coast. The first series covered the period 30 August to 3 September, and two or three forecasts per month were supplied up to February 1942. The forecasts were issued, usually in plain language, to the Naval Staff, but appropriate additions were sometimes also made to the Fleet Synoptic messages with special security precautions, as arranged with the meteorological officers of H.M. Ships concerned.

Army requirements were met by routine weather forecasts and by data on rainfall which were supplied regularly from October 1939. These data were important as a close watch had to be kept on the supplies of fresh water available for the Garrison which depended on storage of rainfall collected on 'catchments.'

R.A.F. requirements were at first met by routine forecasts for areas patrolled by flying boats operating at comparatively low levels. The area covered by these operations was gradually extended; the information was supplied to R.A.F. H.Q., first at the Dockyard Tower and later at New Camp. In January 1940, the supply of a duplicated local daily weather report was arranged and in June regular forecasts of wind at 10,000 feet were started. By that time, the number of route forecasts required for longer routes such as Gibraltar—United Kingdom was beginning to increase.

With the development of an airfield and increase in transit and reinforcement flights, a Duty Pilot's office was set up at North Front and became the recipient of routine weather information in December 1941. The supply of forecasts for the area to 15° W. and 5° E. was stopped when the forecast section moved, as Flight Commanders could then consult synoptic charts at any time. Increasing numbers of non-routine forecasts for transit or reinforcement flights were supplied for the routes to the United Kingdom, Malta and Bathurst. Briefing requirements became a serious strain on the staff until after the transfer of the forecast section, when the complement of forecasting officers was increasing, although even then, travelling between New Camp and North Front took up an appreciable part of the forecasters' time. The situation was eased later when it became possible to set up separate meteorological sections at the flying boat base and at the airfield. The schedule for the exchange of advisory forecasts was often modified as requirements changed and from January 1942, such forecasts addressed to Gloucester were repeated to H.Q. No. 19 Group.

Investigations: Attention was early directed to the study of the distribution of upper-air temperature, occasional observations made in peace-time having shown that, particularly in summer, ballistic temperatures computed from assumed values might be seriously wrong. Occasional observations were received from patrol aircraft, but no aircraft were available at that stage for regular observations.

By arrangement with the Army authorities, instruments were erected on a site on the summit of the Rock and a R.A. unit made observations of temperature from October 1940 to January 1942. These observations and all available observations from aircraft were used to make a preliminary report giving average values for computing ballistic temperatures until a regular

Meteorological Flight was started later. During the period, a number of local meteorological problems were studied as time allowed. Results of these studies were later incorporated in a publication on the weather of Gibraltar.[1]

March 1942 to August 1945

Organisation: During this period, all three Services played a considerably greater part in the war, and their meteorological requirements were constantly expanding and changing until the closing phases. In regard to the Royal Air Force, the emphasis changed largely from anti-submarine patrols to long-distance flights. Army interests in meteorology developed with the installation of anti-aircraft rockets, smoke screens and radar, while special Naval requirements arose from the invasion of North Africa, the use of the unusual vessels developed for landings and, in the earlier stage, the need to supply aircraft to Malta. The plan which was evolved during 1942 to meet these needs consisted of providing a single main forecasting office giving a unified service, as it was clear that within the small confines of Gibraltar it would be most undesirable for the meteorological opinions issued at the same time, even for different types of operations, to diverge in the least. At the same time, the need for a personal forecasting service at various parts of the Rock was to be met by opening, as staff permitted, secondary forecasting offices which promulgated, interpreted and explained the guiding forecasts issued by the main office. This plan was kept in mind when detailed arrangements were being made in the second half of 1942 to meet the needs of the North African invasion. During much of this period, the staff needed to operate the plans were not available, but the general framework was agreed upon with the Meteorological Office and the A.O.C., Gibraltar.

The Royal Air Force organisation was also developing at that time. In addition to the Flying Boat Group of Coastal Command at New Camp, the R.A.F. took over in May 1942, the land base at North Front. About the same time, the administration was stepped up from Group level to an Air H.Q. with, in regard to Coastal Command operations, rather more extensive independence, and with greatly increased responsibilities and control over the aircraft of Transport and Fighter Commands based or passing through Gibraltar.

In order to achieve the closest co-operation with the Navy, an Area Combined H.Q., with an operations room staffed by both R.A.F. and Navy personnel, was developed during the summer of 1942 and was in full operation by October 1942. It was located at first in the Naval H.Q. in the Dockyard (the 'Tower'), but specially constructed offices with meteorological accommodation were being prepared in tunnelling under the Rock and were occupied by the Operations staff shortly before the North African landings in November 1942.

At first, the forecasting requirements of both the North Front airfield and the Operations Room at Combined H.Q. were met by a supply of written forecasts, by telephone and by the attendance of a forecaster on special request. A motor-cycle and sidecar was put at the disposal of the meteorological office, New Camp, for this purpose, but there was still a considerable loss of forecasters' time.

[1] 'Weather in Home Waters', and the 'North-Eastern Atlantic', Vol. II, Part I, Appendix, Gibraltar, M.O.446B, 1943.

The following steps were taken to implement the plan fully :—

(*a*) A briefing office was opened at North Front on 8 November 1942 (D Day for the North African invasion). It consisted of one forecaster per watch with an assistant. Charts were at first supplied already plotted from New Camp. Within the next few days, this office was developed until it became the Main Forecasting Centre for a time. A teleprinter with New Camp was installed on 10 November 1942 and independent plotting began on the 14th, by which time the whole forecasting section had removed from New Camp except for a liaison officer.

(*b*) The Senior Meteorological Officer and administrative staff moved to the Area Combined H.Q. on 14 November 1942 and undertook, in addition to administration, the preparing of charts and briefing the A.C.H.Q. staff. Information was brought, 'phoned or, later, teleprinted from New Camp ; contact was maintained with the duty forecaster at the Main Forecasting Centre and the Senior Meteorological Officer or his deputy began regular attendance at the A.O.C.'s morning conference, a duty which continued until May 1945.

(*c*) A meteorological communications centre was formed at New Camp and reached its final form by 25 November 1942. Meteorological information was received by a W/T section, passed through a decyphering office and distributed by teleprinter to North Front and Area Combined H.Q. Outward messages were similarly handled.

(*d*) The Main Forecasting Centre was transferred from North Front to Area Combined H.Q. on 24 August 1942, and a secondary office was opened in lieu at North Front at the same time. This move, which was part of the original plan, was delayed by lack of staff and accommodation ; its completion marked the final point in the war organisation of the Gibraltar meteorological service.

By the autumn of 1943, after several minor alterations and trial arrangements, the organisation had crystallised into the form in which it remained for the rest of the war. The section consisted of :—

(*a*) S.Met.O and Administration—at Area Combined H.Q.

(*b*) Main Forecasting Office—at Area Combined H.Q.

(*c*) Secondary Forecasting Offices—at New Camp and North Front.

(*d*) Meteorological Communications Centre—at New Camp.

(*e*) Main Observing Office, Store, Workshop and Records—at Windmill Hill Flats.

During the preliminaries for the North African campaign, Meteorological Reconnaissance Flights were begun from North Front using Hudson aircraft at first. Later, specially equipped Halifax aircraft were received. The first meteorological reconnaissance flight was made on 2 November 1942 and flew to 12° W. Vertical ascents, first by Hurricanes, then Spitfires and finally Gladiators, had already begun on 21 May 1942.

The original meteorological office at Windmill Hill was maintained throughout the war. It continued to supply the main synoptic observations for Gibraltar after the departure of the forecasting office to New Camp, and, although

observations later began at North Front also, it remained the only fully equipped observing station with anemometer and pilot balloon equipment until March 1945. It also became the main store for instrumental equipment, stationery and records, but a small emergency stock of equipment was housed in the tunnelling under the Rock when enemy attack and, later, air raids, were expected.

The Senior Meteorological Officer was responsible for all meteorological services at Gibraltar and, while having special responsibilities to the A.O.C. and R.A.F. in general, he was ultimately answerable to the Governor in the event of any conflict arising between the interests of the various services. He personally advised the A.O.C. and the senior Army and Navy authorities, at first irregularly as occasion demanded but, from October 1942 to May 1945, daily at the A.O.C.'s conferences which were attended by Naval as well as R.A.F. Operations Staff. During important operations, a second daily conference was held in the afternoon.

At first, the Main Forecasting Office undertook the direct issue of all forecasts for anti-submarine patrols, including weather in patrol area and at Gibraltar for the return, forecasts for transit flights to U.K., Malta, Bathurst, etc., Fleet Synoptic forecasts, Meteor reports for A.A. and flat fire and smokescreen and chemical warfare forecasts. With the formation of secondary forecast offices at New Camp and North Front, flight forecasts were prepared by the office at the departure point, under general guidance from the Main Forecasting Office.

The meteorological office, New Camp, provided the information needed by the Services using North Front airfield, particularly the forecasts for anti-submarine patrols and transit flights by land-planes. It was also responsible for liaison with the Meteorological Flights and met all their meteorological requirements.

The Meteorological Communications Centre received synoptic data, forecasts and analyses by W/T, decoded these messages and distributed the information by teleprinter to the forecasting offices, received from the forecasting and observing offices the forecasts and observations, encyphered and passed the messages to the appropriate W/T transmitting station and compiled the synoptic sections of the Fleet Synoptic messages.

The staff at the Observing Office, Windmill Hill, made hourly observations for internal use and completed three-hourly observations for general promulgation, maintained records, prepared climatological returns and undertook any required investigations into past records and summaries. They also supplied additional observations required by the forecaster and intercepted and translated verbal forecasts from Spanish broadcasting stations as required.

Royal Air Force Operations : The forecasting service was used increasingly for operations during 1942. Pictorial forecasts were shown in the Area Combined H.Q. from May 1942 and continued with minor changes until the end of the war. Later, when the Senior Meteorological Officer attended the A.O.C.'s conferences, much of the subsequent detailed planning as to likely degree of success, length and possible duration of patrols, convoy escorts, etc., was done by the Senior Navigational Officer and the Senior Meteorological Officer, and submitted to the A.O.C. for final approval. With the transfer of

the Main Forecasting Office to Area Combined H.Q. in August 1943, full co-operation between meteorological and Operations staff was achieved, the forecaster being available at all times for consultation.

Routine operations consisted mainly of anti-submarine patrols, convoy escorts and contraband searches. The longer distance patrols and escorts were performed by Catalina flying boats based on New Camp, while shorter sorties were made by Hudsons from North Front. In both cases, forecasts for the outward and return journeys, the period on patrol and conditions for return at Gibraltar were given. Particular attention was paid to the worst landing conditions likely to be met on returning, as until Port Lyautey, La Senia and other North African bases became available in December 1942, there were no possible diversion airfields or flying boat bases within 1,000 miles of Gibraltar.

As work on the runway extension became more complete in 1942, an ever-increasing number of transit flights was made. At first, the routes to be considered were mainly those to the United Kingdom and Malta but, later, direct flights to Middle East, Bathurst, the Azores and all bases in North Africa were added.

The Meteorological Organisation for Overseas Flights (M.O.O.F.) came into effect between Gloucester and Gibraltar in 1943, but communications limitations prevented the introduction of the full procedure of flight forecast exchanges between terminals and the supply of amendments to aircraft in flight.

After the North African landings, Gibraltar also met the forecasting needs of some Moroccan and Algerian bases, principally La Senia and Ras-el-Mar (Fez). From 9 August 1942, forecasts were issued daily for flights first from Gibraltar itself and later from La Senia to Kano.

The Senior Meteorological Officer made special arrangements and gave personal briefing for a number of V.I.P. flights. A special forecast was also issued for a flying boat landing in the open sea off Toulon on 6 November for a rendezvous with a submarine carrying the escaped General Giraud. Passive Air Defence (P.A.D.) forecasts, dealing with the local conditions for air raids, were issued daily to the R.A.F. P.A.D. officers from June 1942. In this connection, special forecasts were prepared for a time in 1942 following information that aircraft raiding Gibraltar were landing in the Balearic Islands on the return journey. It was considered that if headwinds from Italy to Gibraltar were too strong, or conditions in the Balearics were unfavourable, no raid need be expected.

On the night of the North African invasion and for several days afterwards, very frequent forecasts were given for fighter aircraft leaving Gibraltar for the newly captured Algerian airfields.

Army Operations : The main Army requirement was for Meteor reports for both flat fire and A.A. firing and was met according to routine procedure. Forecasts of conditions at Gibraltar in relation to the possibility of a chemical warfare attack were begun in June 1942 and contained an estimate of expected conditions of wind, humidity and turbulence.

Various trials of smoke screening small sections of the Rock were made in 1942 and 1943 when suitable conditions were forecast. In addition staff of the meteorological section observed the drift of smoke and, each time, obtained useful information regarding the local wind eddies.

Navy Operations : Routine Fleet Synoptic messages were issued daily for H.M. Ships at sea and the information supplied to the R.A.F. Operations staff at the Area Combined H.Q. was available to Naval staff. From 17 May 1942, a series of special forecasts and extra synoptic data were added to the Fleet Synoptics when H.M.S. *Eagle* was engaged on despatching aircraft to Malta.

Special attention was paid to sea swell and surf conditions during the North African invasion. A Naval Meteorological Officer was attached to Gibraltar during the period and worked in co-operation with the Meteorological Office staff for about two months. Forecasts of sea and wind conditions were supplied for Tank Landing Craft which were used extensively after the invasion to convey stores and personnel around the Mediterranean ports. Similar special forecasts were issued when damaged ships had to be towed.

As currents and tides were found to influence enemy submarine movements through the Straits of Gibraltar, the A.O.C. and the Admiral asked the Senior Meteorological Officer to correlate the available data. Data from two trials with British submarines were available, together with enemy documents based on an earlier Danish oceanographical expedition. A summary was prepared giving graphs which supplied for the first time, the estimated speed of water movement at any part or depth of the Straits at all states of the tide and at each season of the year. At least twice, the drift of enemy submarines during some hours of search was determined very precisely.

In August 1944, airmen of the meteorological section were loaned to the Navy for an experiment involving the release of pilot balloons carrying radar decoy devices from a submarine.

Co-operation with the American Forces : Units of the U.S.A.A.F. and U.S. Navy first went to Gibraltar during the preparation for the North African invasion at the end of 1942 and obtained meteorological information from the British meteorological office. For the actual invasion and for a short while after, there were a number of U.S.A.A.F. meteorological officers, the first of whom arrived on 20 October 1942. They were given all co-operation and information, and no great difficulty was found in meeting the needs of the U.S. Forces. Later, forecasts and synoptic data required by the U.S.A.A.F. at La Senia and Port Lyautey were supplied upon request, and a special collective of synoptic data was sent out regularly for a long time to both U.S.A.A.F. and U.S. Naval Aerological Offices at the latter base.

The anti-submarine patrol in the Straits was largely taken over in 1944 by airships and Catalina aircraft operating from Port Lyautey, both equipped with a special magnetic anti-submarine device. Special forecasts for the Straits and landing at Gibraltar were issued to Port Lyautey, after all the operational details had been discussed at a meeting at Casablanca with the U.S. Naval authorities, attended by the Senior Meteorological Officer at Gibraltar. For a time, a portable airship mooring mast was available at Gibraltar, and a few trial moorings were made in specially selected wind and weather conditions.

U.S. aircraft using Gibraltar as a stopping place were provided with forecasts in the same way as for R.A.F. transit flights. One Wing of U.S. paratroop aircraft passed through Gibraltar several times from the United Kingdom to the scene of operations in Italy and Southern France and back, and nearly 100 D.C.3 were briefed simultaneously for this flight.

Communications : At the beginning of the period, the collection of synoptic information depended largely upon cable messages from United Kingdom, but facilities for radio reception were also available and were used to collect observations from Spain, Portugal and the Azores. It was learned in June 1942 that a W/T collective message was being sent from United Kingdom to Iceland, and Air Ministry were asked for details of the transmission and codes. These showed that the messages could be intercepted quite reliably and they then became normal means of obtaining the bulk of the synoptic data required at Gibraltar. Later, these messages were transmitted specifically for the benefit of Azores, Lisbon, Faroes, Iceland and Gibraltar, and were designated by the recipients' initials—ALFIG. During the North African invasion period, the ALFIG transmissions were specially extended to cover the detailed forecasts necessary for that operation. Additional broadcasts were received at Gibraltar as the course of the war developed and by 1944, broadcasts from Malta, Algiers, Dakar, Italy and West Africa were regularly received in addition to those listed above.

Synoptic observations made at Gibraltar were transmitted by cable until late in 1942. From mid-1942, however, messages were also sent to United Kingdom by W/T point-to-point and when this method was found satisfactory the cable signals ceased. At first the W/T transmissions were made at a variable time depending upon the state of R.A.F. traffic, but later in 1943 both time and frequency were fixed so that other recipients, notably the Azores, could intercept them. These messages at first contained only the surface and pilot-balloon observations from Windmill Hill, but later included surface reports from North Front, aircraft observations and, for a time, observations from Ras-el-Ma and Rabat Sale.

From the beginning of observations at North Front, a regular supply of hourly reports was passed to Flying Control for transmission to aircraft in flight. It was learned in 1943 that, on the instruction of the A.O.C., the un-cyphered version of these reports was being transmitted, thereby compromising the cypher used for point-to-point transmission of the same material. The matter was referred to the Meteorological Office, it being pointed out that the A.O.C.'s decision was based on the almost certain availability to the enemy of observations from within Spanish territory, less than a half mile away. As a result, from the beginning of 1944, all surface observations made at Gibraltar were transmitted in clear.

Except for one short break, W/T broadcasts were received at New Camp. For a trial period of ten days, the meteorological W/T section was transferred to the R.A.F. 'Rock W/T' station at the extreme south end of the territory but, owing to the difficulty in ensuring regular transmission of the collected data by teleprinter to New Camp, the trial was not regarded as successful. The data received were passed to a decyphering section and then to the forecast room. With the opening of offices at North Front and Area Combined H.Q., a teleprinter network was installed in October 1942 and a simultaneous broadcast was made by that means. Observations, forecasts, etc., prepared at Gibraltar for a retransmission were similarly passed by teleprinter to the cyphering section and the resultant encyphered message sent to the R.A.F. communications system for dispatch. Several tests were made to determine whether adequate reception could be obtained at North Front, but unfortunately no good site free from interference could be found. New Camp was also made the

centre of a private telephone network joining the meteorological offices at North Front, A.C.G.Q. and Windmill Hill with an extension to the R.A.F. transmitting station. A small switchboard operated by the meteorological cypher staff was provided.

Observations : Surface observations were made hourly at the meteorological office at Windmill Hill Flats, a plateau about 400 feet above sea level at the south end of the Rock. A Dines recording anemometer having been dismantled earlier in the war, wind measurements were made by cup anemometer but standard equipment was used in other respects. Observations were transmitted to United Kingdom and other bases outside Gibraltar at the synoptic hours. Steps were taken during 1942 to re-erect the Dines anemometer, and recordings recommenced on 1 July 1943.

Observations began at North Front on 15 November 1942, and were made hourly from that date ; the observations were included at synoptic hours with the Gibraltar transmissions. A Dines anemometer was installed and was brought into operation in March 1945.

By arrangement with local squadrons, a daily vertical ascent to 500 mb. was made whenever possible from North Front. From 21 May 1942, these flights were made by Hurricanes of the Merchant Ship Fighter Unit based at Gibraltar but from 16 September 1942, ascents were made by Spitfires of a unit responsible for the assembly of these aircraft at Gibraltar. In June 1943, three Gladiator aircraft were received specifically for meteorological duty and regular ascents continued until 25 April 1944 when, no further serviceable Gladiators being available, vertical ascents ceased. Standard mercury-in-steel aircraft thermometers were used throughout but, except when the Gladiators were available, no wet-bulb readings could be obtained.

The first meteorological reconnaissance flight from Gibraltar was made on 2 November 1942 using a Hudson aircraft. Whenever possible, a daily flight was made westwards over a track of about 400 miles, but as the establishment was only for the single aircraft, complete regularity could not be obtained even with the help of the Hudson squadron (No. 233) based at North Front. This flight was given the code-name 'Nocturnal'. No Meteorological Air Observers were available during this period, but the Navigator of the Hudson had had special training and meteorological airmen also undertook flying duties voluntarily. In February 1944, Halifax aircraft of No. 520 Squadron took over this flight, whose trace was extended to a total sortie of 1,400 miles. This squadron was specifically allocated for the duty of Meteorological Reconnaissance Flights, and an establishment of Meteorological Air Observers, under a Leader, was provided. Very regular sorties were made thence onwards. For a short time, when no available Halifax was serviceable, Catalina aircraft of No. 202 Squadron undertook sorties.

The close connection between the local surface sea temperature and the formation of fog was early appreciated. From 30 May 1942, a daily run by R.A.F. boat was arranged for the purpose of measuring sea temperature about one mile from the shore. Three observations were maintained with considerable regularity from then onwards. The opportunity was taken during these runs to observe sea swell, while practical instruction in the effect of swell on flying boat operations was given to forecasters by flying boat captains who accompanied the run on occasions.

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No cloud searchlight was available at Gibraltar and the measurement of upper winds was limited to pilot-balloon methods. It was therefore arranged with the A.A. H.Q. for a vertical searchlight to be lit on request, while shell-bursts for the determination of upper winds at considerable height were provided when required by the forecaster. These arrangements came into force in October 1942 and proved of great value.

During 1942, the A.A. Brigade installed a number of anemometers at A.A. Rocket sites around the Rock. From July 1942, for a period of about 18 months, a record of the readings from these anemometers at 0900 daily was supplied to the Meteorological Office for use in investigations into the local wind eddies.

Observations on the drift of smoke were also made in order to investigate the local eddies. With the co-operation of the Army Chemical Warfare Office, smoke generators were fired at chosen sites and observed from higher levels on the Rock and by aircraft.

In order to overcome the limitations of visually followed pilot balloon ascents, particularly when it was wished to determine the depth of the easterly winds above the Levanter cloud, balloons were released with light aerials, and were followed by Army radar Type G.L.II. The results were not very accurate but helped to give a qualitative idea of the upper wind structure. These observations were first made in March 1944 and were continued intermittently as the necessary arrangements could be made.

Technical Problems and Special Work

The main factors to be considered in determining the fitness of the weather for landings at Gibraltar were the possibility of fog and the direction and turbulence of the wind. The main risk of widespread fog occurred when warm damp air came from the east after a spell of westerly winds. The sea temperature data were of great value in determining the likelihood of fog and the length of time it would persist. Continuous fog, clearing only over the land during the day, for a period of up to four days, was often experienced after such a wind change. The earlier work of Field[1] had concentrated attention on the danger of the eddies forming in the east winds, as at the time of these investigations, the concern was for aircraft landing on aircraft carriers to the west of the Rock. With the building of a runway from east to west, at North Front, at the north of the main bulk of the Rock, it soon became clear that the main danger arose with south-west winds, the turbulent area of which lay across the line of approach to the runway and very close to the eastern end of this. Other wind directions could cause severe bumpiness to aircraft on the approach circuit but did not interfere with landings.

Anti-submarine and patrol operations presented no special meteorological problems. The success of patrols depended on the extent of visibility and cloud height in the patrol area while, until the end of 1942, when alternative bases in North Africa became available, very great care had to be taken to recall aircraft from patrol before the landing conditions at Gibraltar could deteriorate. The same considerations applied equally to transit aircraft passing through Gibraltar. Particular difficulty was experienced within the Straits in the use of Asdic methods of submarine location, caused mainly by the differences in temperature and density which existed and resulted in anomalous reflections of the Asdic beam. In addition, the subsequent movements underwater of a submarine which had been momentarily sighted or detected were most difficult to anticipate, both by the attackers and by the submarine itself, as a result of the very strong tides and currents in the area. The Senior Meteorological Officer prepared a report on the strength of the currents.

[1] *See* Geophysical Memoir No. 59, 1933, M.O. London.

A series of operations was undertaken during the summer of 1942 by H.M.S. *Eagle* to reinforce the Malta Fighter Squadrons. Spitfires, assembled at Gibraltar and fitted with long-range tanks, were placed on the *Eagle* and carried to a point off Algiers or south of Corsica where they were flown off the carrier to Malta. The weather for this operation was important as winds of more than 15 m.p.h. at ' take-off-point ' were essential, with the minimum of headwind for the rest of the journey, Sea swell and landing conditions had also to be considered. The runs were made only after consultations between the Senior Meteorological Officer, Gibraltar, and the Naval Meteorological Officer, *Eagle*. Special observations and forecasts were added to the Fleet Synoptic during the voyages of the *Eagle*, to help the Naval Meteorological Officer on board, while the time of the ' take-off ' operation was closely controlled by the Combined R.A.F. and Naval Operations staff at Gibraltar, to whom the Senior Meteorological Officer supplied continuous advice. After several runs, the operations ceased when H.M.S. *Eagle* was sunk.

After T.R.E. issued a report in 1943 on conditions of anomalous radar propagation, forecasts were supplied to the R.A.F. and Army from 8 February 1944 giving the upper air conditions of temperature and humidity lapse rates around Gibraltar and in an area west of Portugal in the form of diagrams.

Before the Allies landed in North Africa in November 1942, a considerable amount of meteorological advice was supplied for the anti-submarine patrol guarding the approaching convoy. As the convoys approached their destination, forecasts of swell took prior place. During this period, a U.S. meteorologist attached to Gibraltar began to issue long-period swell forecasts based on analogues, the first being issued one month before the event. Immediately before the invasion, the indications on this system were that a heavy swell, caused by a strong north-westerly wind over mid-Atlantic, would reach the North African coast. Local experience suggested that the prevailing strong easterly wind, blowing through the Straits, would produce a local easterly swell and that in the area west of the Straits there would be a heavy ' chop ' in which much of the energy from the north-westerly wave stream would be dispersed, resulting in quiet conditions on the North African coast. The advice given by the U.S. and British meteorologists was thus in complete contradiction. As it was the U.S. portion of the invasion fleet which would be affected, the Supreme Commander accepted the U.S. meteorologist's advice and that part of the invasion was instructed to delay 24 hours. On D minus 1 (7 November), the U.S. meteorologist was persuaded to visit the area of the ocean concerned on a meteorological reconnaissance aircraft. He found little swell, but it was then too late to restore the invasion time to its original scheme.

For planning operations, data giving the average conditions to be expected month by month proved to be most useful. Summaries of all useful elements of the weather were prepared in monthly form and issued to all interested

authorities in the three Services. Monthly statements of the weather in the preceding months were issued to Intelligence Officers to assess the effect of conditions on operations.

Malta

Throughout the war, meteorological data were supplied to meet the extremely varied operational needs of all branches of the fighting services: the R.A.F. needed advice for fighter, reconnaissance, bomber and transport operations and occasionally for special parachute operations over enemy-occupied territory; the Navy needed forecasts for the reconnaissance and torpedo bombing operations of F.A.A. units based at Hal Far and for the surface and submarine operations carried out within or adjacent to the Central Mediterranean; the Army needed data in connection with A.A. and coastal defence gunnery, chemical warfare and beach landings in Sicily. Operational activities were complementary to those of the Middle East, but there were a number of well-defined phases which mainly coincided with successes and failures of the forces in Greece and Crete and the Western Desert.

Organisation

The forecasting centre was at St. John's Cavalier, on the north-western side of Valetta, until Italy entered the war on 10 June 1940. From then until 3 June 1941, the forecast and W/T staffs were located in the R.A.F. and Air Defence H.Q. which had been set up in a large protected chamber within the Cavalier; observational work continued in the original offices. In May 1941, the R.A.F. Air Defence War Room activities were moved underground at Lascaris Barracks, east of Valetta, and on 3 June the forecast, W/T and cypher sections moved to temporary accommodation in three cubicles in the passageway leading into the underground H.Q. On 1 April 1942, the observational and administrative offices of the meteorological centre at St. John's Cavalier were almost completely destroyed by a bomb and the Lascaris cubicles were made untenable three days later by another bomb. Fortunately, the W/T staff had been transferred to the R.A.F. Inter-Command W/T Room in underground accommodation on 23 March. For about a week, the forecast and cypher sections worked in the R.A.F. underground accommodation in a room which was needed for the termination of a direct Malta—Alexandria cable. Meanwhile, the Navy had placed at the Senior Meteorological Officer's disposal a naval hut, in Lascaris Ditch within the precincts of the Combined H.Q., to which the forecast and cypher sections were moved as soon as the necessary telephones had been installed. A day later, blast made it uninhabitable. Meteorological work was then moved back to the 'cable' room, the Air Officer, Administration, allowing the Senior Meteorological Officer to use the room only until the passage cubicles had been made fit for occupation. Work was resumed in the cubicles on 19 April. Meanwhile priority construction of cubicle accommodation for observational and administrative offices in the tunnel at St. John's Cavalier had been approved. Also, the Lascaris area was combed for places which would permit of forecast, W/T and cypher work being continued without interruption during heavy raids. The only possible location was a part of a sloping tunnel leading down into Lascaris Ditch and was occupied on 26 May. During July 1942, the one room at the top of St. John's Cavalier capable of repair was made habitable for the assistant on observational duties, thus making a continuous weather watch again possible. As W/T

reception was far more reliable in the Lascaris offices than in the Inter-Command Room, suitable aerials were erected and the W/T section as a whole moved there in September 1942, thus reuniting forecast, W/T and cypher sections. On 23/24 December 1942, most of the Lascaris meteorological office tunnel was flooded and the forecast and cypher sections were transferred to four rooms of the St. John's Cavalier offices which had been rebuilt by then. The small cubicles in the St. John's tunnel were arranged so that these sections could be moved into them if heavy air raids recurred and were, in fact, used during night raids. At that stage, the W/T section could not be moved to St. John's as a powerful standby transmitter was installed there and, if brought into use, would have blotted out all W/T reception. A runner service was, therefore, necessary between the two offices. By October 1943, it was decided that the standby transmitter would not be needed and the W/T section was transferred to St. John's Cavalier, thus reuniting the three sections. Rebuilding of the remaining bombed offices on St. John's Cavalier was completed in January 1944.

A Type 4 meteorological office operated at the Ta Qali Civil Airport from 17 November 1938 until 27 November 1939 when the airport was officially closed, civil aircraft being instructed to use Hal Far pending the completion of a new landing ground at Luqa. However, Imperial Airways aircraft continued to use Ta Qali whilst Italian aircraft used Hal Far until 29 January 1940 when the Luqa runway became serviceable. During this period, the assistant was based at Valetta and went to Ta Qali or Hal Far when required by the Civil Airport Controller.

Luqa airfield was used increasingly by Imperial Airways, Ala Littoria and Air France up to June 1940 after which it was increasingly used for all R.A.F. operational activities—photographic reconnaissance aircraft, day and night bomber, torpedo-bomber, fighter and transit aircraft. It was fully appreciated throughout the period 1940–1942 that meteorological requirements at Luqa could only be met by setting up a subsidiary forecast office there, but the accommodation problem remained unsolved. In the autumn of 1943, however, the establishment of a Type 3 office, as soon as staff became available, was authorised. The office was opened at Luqa on 12 December 1942, thus overcoming the serious handicaps involved in the lack of personal contact between forecasters and aircrews and of briefing facilities at an airfield from which medium and long range aircraft were continually operating. The office was at first above ground but on 28 February 1943 it moved to the underground operational H.Q. It moved back to an office above ground on 20 November 1944. Forecasts and synoptic information were passed to Luqa by telephone or teleprinter from the central office at Valetta, but communications were not satisfactory until a direct meteorological teleprinter circuit between the two offices was installed on 20 November 1943.

Auxiliary stations at Gurdan Lighthouse, Gozo and R.A.F. Stations Kalafrana and Hal Far supplied abbreviated reports to the Valetta office until the autumn of 1940 when the absence of No. 202 Flying Boat Squadron from Kalafrana and Service commitments at Hal Far caused the cessation of these reports from the two R.A.F. stations. In order to meet the needs of flying boat operations, however, observations of the state of sea and swell in the inner and outer bays at Kalafrana were supplied regularly by that station from 20 December 1940. The Gozo reports continued throughout the war on a regular basis and proved of considerable value.

Meteorological Flights

An average of 25 upper air temperature flights per month was made at Hal Far by Tudor or Swordfish aircraft until June 1940. From then until January 1941, operational requirements reduced their frequency to about 15 per month. It was arranged in January 1941 for a Gladiator to be used for approximately daily ascents to 400 mb. Twenty-seven flights were made in February but only four were made in March owing to damage by enemy action to the Gladiator and its equipment. No flights were possible from April to August, but they were resumed on an almost daily basis from mid-September until early in January 1942. After then, the frequent presence of enemy patrols of Me109F aircraft made Gladiator flights too risky. The question of resuming flights using Hurricanes was raised with the Air Officer Commanding in May when local air superiority was being regained, but permission was refused on account of the acute shortage of aviation fuel. The loss of regular upper air data was a serious handicap to the Malta forecasting service and steps were taken to secure the resumption of flights as soon as the petrol situation warranted it. In May 1943, therefore, a Luqa-based Spitfire was detailed for the task and routine ascents were recommenced. On 16 June 1943, the Meteorological Flight was transferred to Safi and subsequently, on 15 October 1943, to Hal Far.

Synoptic Broadcasts

Malta synoptic reports were normally broadcast by the Naval W/T station at Rinella but during the emergency period just before the war, these transmissions were replaced by similar ones made by the R.A.F. In accordance with the War Organisation, these were discontinued from 2 September 1939 until, in view of the anomalous situation in the Central Mediterranean, their recommencement in International Code was authorised on 15 September. Meanwhile, in compliance with the explicit instructions of the A.O.C., reports were transmitted to Sicily and Tripoli for the information of the Italian Civil Air Services as in peace-time. On 1 April 1940, the transmissions were keyed by the meteorological W/T operators from the W/T room in the Cavalier Offices instead of from R.A.F. H.Q.

When Italy entered the war, the broadcasts were again discontinued and reports were cabled to London, Gibraltar and Almaza at the four fundamental hours in Confidential Meteorological Code. Alexandria was added to these addresses on 19 August 1940. From 17 September, cables to London and Gibraltar were superseded by the use of Inter-Command W/T channels for these addresses.

During December 1940, the C.-in-C., Mediterranean, asked for Malta weather reports, upper winds and upper air temperatures to be broadcast by the Naval W/T station. By arrangement with the Port W/T officer, transmissions in Confidential Meteorological Code (C.M.C.) began on 9 December. A further small reduction in cable traffic (to Almaza) could then be made but cables to Alexandria and the Inter-Command transmissions to London and Gibraltar had to be continued. At the request of the C.-in-C., weather reports received from Malta-based reconnaissance aircraft were included in these messages wherever possible.

All transmissions on 27 September 1941 were made on the Naval M/C routine instead of on the broadcast routine, but Middle East units soon complained regarding punctuality and signal strength, and as the Port W/T officer could effect no appreciable improvement, the Chief Signals Officer, R.A.F., was asked to arrange a broadcast. This was begun on 21 October, and included reports for the four fundamental synoptic hours only. The Naval transmissions were discontinued on 2 November. As before, aircraft reports, upper winds and temperatures were included in messages whenever they were available. Satisfactory reception of the R.A.F. broadcast being reported by London, Gibraltar and Middle East, the transmissions to London and Gibraltar via Inter-Command channels were then discontinued.

Until 26 February 1943, the broadcasts were made four times daily, but on that date, broadcasts of the 0400, 1000 and 1600 G.M.T. reports were added. From May 1943, upper air temperature reports and upper winds measured by shell burst observations were regularly included in the broadcasts, as well as the usual pilot balloon and aircraft reports.

During the Sicilian campaign, twelve-hour forecasts for Sicily were transmitted with the synoptic broadcasts for the advice of the mobile meteorological units in Sicily. The synoptic reports collected from these units were included in the Malta broadcasts.

Facilities for Aviation

R.A.F. Operations : Until December 1942, the main forecasting centre met the meteorological needs of the A.O.C. and the R.A.F. stations at Luqa, Ta Qali, Hal Far and Kalafrana. The work consisted mainly of providing forecasts for reconnaissance, bombing, torpedo attacks on enemy shipping, anti-submarine patrols, mine laying, fighter defence, low-level attacks on road transport between Tripoli and Benghazi and, occasionally, parachute dropping. Forecasts were passed to the operational stations by telephone or teleprinter.

After Italy's entry into the war and the collapse of France, the lack of vital synoptic data from Italy, France and French North Africa was an extremely severe handicap to the Malta forecasters. Moreover, much of the flying activity took place at night when the low stratus hazard, which, particularly at Malta, is difficult to forecast precisely, had to be taken into account. The fact that, until all North Africa came under Allied control during 1943, no emergency alternative landing ground was available for Malta-based and Malta-bound aircraft, made the problem even more difficult.

Towards the end of 1942, the meteorological service was strengthened by the arrival of additional officers and, with accommodation becoming available, it was possible to provide improved facilities by setting up at Luqa a Type 3 office which met the needs of the various units there, including H.Q. No. 232 Light Bomber Wing. Moreover, the occupation of North Africa in 1943 eased the difficulties of the Malta forecasters by increasing the amount of synoptic data available.

In June 1943, No. 12 Mobile Met. Unit arrived in Malta before going to Sicily as soon as the Desert Air Force, to which it was attached, became established there. However, throughout the period of the Unit's attachment, the Malta meteorological service continued to be responsible for all operational forecasting which, by then, included the requirements of the new R.A.F. stations Krendi, Safi and Gozo, H.Q., T.A.F. and Light Bomber Force.

Forecasts for Malta and the area within 100 miles radius, and including upper winds to 30,000 feet, were supplied to Fighter Control four times daily all the time that Malta was subjected to air attacks.

Transport, Delivery and Civil Flights : Until the fall of France, forecasts and reports were supplied for civil aircraft operating on the routes United Kingdom—Marseilles—Tunis—Malta—Sollum—Alexandria—Calcutta ; United Kingdom—Marseilles—Tunis—Malta ; Tripoli—Malta—Syracuse—Naples—Rome ; Malta—Catania—Palermo—Naples—Rome ; Malta—Tunis—Marseilles; Marseilles and Malta—Sollum—Alexandria—Beirut. Thereafter, forecasts were supplied more or less regularly throughout the siege for flying boat and landplane services operated by B.O.A.C.

In connection with transport and reinforcement flights from the United Kingdom to Malta and the Middle East, forecasts for the route Marseilles—Malta were transmitted in C.M.C. to London for Gloucester twice daily from 13 October to 7 December 1940. Thereafter the forecasts were limited to the route Cape Bon—Malta but were issued thrice daily until the service ceased on 15 May 1941, by which time the route via Gibraltar had become the regular one for these flights. For a short time during March 1941, the direct route was extended to Benghazi and forecasts for the section Malta—Benghazi were added to the Cape Bon—Malta forecasts.

In order to meet forecasting requirements in connection with Sunderland flights between Gibraltar and Malta, forecasts for the Algiers—Gibraltar and Algiers—Malta sections of the route were often interchanged between the two terminals from February 1941. The flow of reinforcement aircraft was such that these exchanges were out on a daily basis from June 1941. Between September and December 1941, many direct flights between the United Kingdom and Malta were again made and forecasts for the Sardinia—Malta and Marseilles—United Kingdom sections of the route were exchanged with O.A.C. Gloucester. Procedures were revised in January 1942 and routine forecasts were exchanged twice daily with Gibraltar, Almaza and Gloucester but the service with the latter reverted to a request basis in April 1942 owing to the few flights made by the direct route.

Landing forecasts to the Malta Operations Room for broadcast to incoming aircraft some two hours before estimated time of arrival were supplied from August 1941. This procedure was developed in May 1942 when the expected wind direction and speed at 2,000 feet between Cape Bon and Malta were broadcast for the periods when delivery aircraft would be traversing that section of the route from Gibraltar or the United Kingdom. These broadcasts were made at fixed times for each month, approximately one hour after sunset and two hours before sunrise. The messages were encyphered by the Duty Controller in R.A.F. syko. Landing forecasts for Luqa were added to the after sunset broadcast in ZYA form (C.D.75). The broadcasts were repeated five times in order to ensure as far as possible their accurate reception by the incoming aircraft on whom W/T silence was imposed.

Regular R.A.F. transport flights between Malta and Cairo and between Malta and Gibraltar operated from 1942 and, with the occupation of North Africa, flights could be routed to and through Malta by day as well as by night. From the summer of 1943, forecasting for transport flights was the main service of the Malta meteorological office to the R.A.F.

Facilities for the Royal Navy

Fleet Synoptic Broadcasts : Meteorological messages were broadcast daily at 1030, 1600 and 2130 G.M.T. from September 1939 until 14 March 1940. On the latter date, the 1600 G.M.T. message, containing synoptic data only, was discontinued. The other messages contained forecasts for all Mediterranean areas east of longitude 5° E., inferences, frontal analyses, synoptic data, upper winds and upper air temperatures. They were issued wholly in C.M.C. from 27 August 1939 to 9 October 1939 when certain security relaxations were authorised. From then until 10 June 1940, the messages were issued in two parts, the first in C.M.C. containing forecasts, inferences, frontal analyses and synoptic data for security areas, and the second in International Code containing non-secret synoptic data from neutral countries. Full security procedure was reverted to on 11 June 1940.

On 19 June 1940, the morning transmission was replaced by one originated by the Alexandria meteorological office and on 7 July, the evening transmission was similarly replaced. On 9 February 1941, at the request of the C.-in-C., Mediterranean, the preparation of Fleet Synoptic Messages reverted to the Malta office, the broadcasts being retimed for 1130 and 2330 G.M.T. Just before then, on 10 January, a naval meteorological officer was appointed to the Malta office for liaison duties ; he also helped to prepare and encode Fleet Synoptic Messages. In March 1941, the times of transmission were again retarded to 1200 and 001 G.M.T. Another change was made on 1 February 1942 when Part III, the synoptic data section, was transmitted at 0930 and 2130 G.M.T.

The C.-in-C. was told on 8 April 1942 that the various misfortunes of the Malta office might result in a break in the transmission. He replied that Alexandria would take over whenever Malta wished. A further signal, received on 12 April, stated that Alexandria would prepare the Malta Fleet Synoptic Messages from 13 April. Although prepared at Alexandria, the messages were cabled to the R.N. W/T station, Malta, for broadcast at the usual times and on the usual frequencies. As a result of improved conditions at Malta during 1943, the Malta office resumed the responsibility for preparing the messages on 1 November.

Operational : Until Italy entered the war, forecasts, gale and storm warnings for the Fleet Synoptic Areas were supplied to the Port W/T Officer for dissemination to the Naval Staff and Contraband Control Service.

In connection with the Fleet Air Arm attack on the Italian Fleet at Taranto, weather reports, upper winds and temperatures were supplied to Vice Admiral, Malta, from 1800 G.M.T., 10 November to 0700 G.M.T., 14 November 1940 for broadcasts to Rear Admiral Air (R.A.A.) in H.M.S. *Illustrious*, the C.-in-C. and other units of the Mediterranean Fleet. Special forecasts for the air operations were similarly supplied on 11 and 12 November. The forecast of unfavourable conditions for the night of 12–13 November caused a proposed second attack to be cancelled. Reconnaissance flights from Malta that afternoon and the following morning confirmed the forecast layer of strato-cumulus over the target area which represented unsuitable conditions for the medium level and dive-bombing attacks planned as integral parts of the operation.

On 18 December 1940, a special forecast was supplied for the C.-in-C., Vice Admiral Light Forces and Rear Admiral Air in connection with the bombardment of Valona. It contained a warning of a strong risk of Bora conditions along the Adriatic sea-board and, as a result, the air attack and air spotting for the guns were cancelled. Bora conditions did not, in fact, materialise.

Special forecasts for the route to Malta from the ' fly-off ' point were several times provided for Force H when reinforcement Hurricanes for Malta were dispatched from an aircraft carrier.

From 7 December 1940 until 29 August 1941, forecasts of the state of sea and visibility in certain sea areas were supplied each evening to Naval staff for broadcast and interception by Malta-based submarines on patrol.

Many special forecasts were issued in 1941 for various Naval operations including those of convoy escorts through the Mediterranean to Malta, Greece and Egypt, the passage of *Illustrious* to Alexandria after her survival from enemy attacks while on convoy escort and under repair at Malta, and the Greece and Crete campaigns including the battle of Matapan and the evacuations. Forecasts were also supplied for the operations of the 5th and 14th Destroyer Flotillas while Malta-based in the spring, and those of Force ' K ' in the autumn. Special forecasts were also issued to Gibraltar, Force ' H ' and H.M.S. *Ark Royal* during the year when reinforcement Hurricanes were dispatched from the carrier to Malta. These included route forecasts with upper winds to 10,000 feet.

During 1942, special forecasts were mainly required for submarine operations, the Malta convoys and the aircraft carrier Spitfire deliveries both of which necessitated major Fleet operations.

Early in 1943, Force ' K ' could again be based at Malta and for the first time since 1939, direct liaison could be established with this formation through the Naval Meteorological Liaison Officer. The services provided during this period included regular broadcasts for certain sections of the North African coast for the guidance of coastal convoys of small vessels.

The C.-in-C. re-established his H.Q. at Malta in July 1943. Upper winds and upper air temperatures over the Sicilian coasts were broadcast for the benefit of units of the Fleet engaged in bombarding targets in Sicily. During the critical period immediately before and after the landings in Sicily, continuous contact was maintained with Naval H.Q. and twenty-four hour forecasts covering Malta and South-East Sicily were issued to the C.-in-C.'s staff. On the eve of the invasion, a strong northerly wind sprang up in the Mediterranean, but it was forecast that this wind would moderate considerably by the 11th and that there would be only a light wind and slight sea on the south-east coast of Sicily; the first landing craft to beach did, in fact, report calm conditions.

Until major operations in this area ceased, a number of forecasts for special operations were broadcast for information of the Fleet in addition to Fleet Synoptic Messages. Liaison was also once more effected with the Naval Meteorological Officers appointed to ships of the Mediterranean Fleet.

Facilities for the Army

Flat fire and A.A. Meteor messages were prepared and passed twice daily to R.A. units until 11 June 1940. For the remainder of the war, these Meteor

messages were issued four times daily. Owing, however, to the need to conserve hydrogen supplies, the wind components for the noon messages were estimated and not computed from actual measurements until the build-up in 1943 ensured adequate supplies.

Routine forecasts for the Malta vicinity were issued four times daily to the General Staff, H.Q. (Northern and Southern) Malta Infantry Brigade and Commandant, Royal Artillery. From February 1941, G.S.O.III (Chemical Warfare) also received the forecasts to which, for this recipient, were added the forecast mean wind speed and direction between the surface and each 2,000 feet up to 10,000 feet.

From June 1941, the 4th Searchlight Regiment was supplied each afternoon with forecasts of wind speed and direction for each 2,000 feet to 10,000 feet, for 15,000 feet, and for 20,000 feet. The forecasts also included weather, cloud and visibility data, the latter with special reference to haze between the surface and 20,000 feet. From September 1941, the upper limit was raised to 30,000 feet. The haze information was particularly valuable when desert dust haze effectively blanketed searchlight beams, making them useless for illuminating targets and serving only to disclose the exact locality of the island to raiding aircraft.

Special reports and forecasts were supplied from May 1942 whenever required in connection with the projection of harbour smoke screens.

During the Sicilian campaign, forecasts were issued daily for the South-East Sicily area to H.Q. 15th Army Group and Eighth Army.

Facilities for Combined Services

In addition to the information provided separately to each Service, the Operations Room, Combined War H.Q. was supplied, as a routine, with local forecasts and upper winds to 30,000 feet for Malta and 100 miles radius.

Communications

Inter-Command W/T channels to H.Q. R.A.F. Middle East, R.A.F. Gibraltar and Air Ministry enabled the Malta meteorological office to act as a relay station for synoptic data required from time to time by those centres and to transmit Malta reports to such of them as could not intercept the Malta synoptic broadcasts.

When the 1600 G.M.T. Fleet Synoptic ceased on 13 March 1940, H.Q. Middle East asked Malta to relay messages containing up to 25 representative Italian, Greek and Libyan 1390 G.M.T. reports and three pilot balloon reports. The service continued until 11 June 1940 when Air Ministry instructed Malta to begin relaying to Air Ministry and Almaza, four times daily, a selection of North African and Greek reports. French North African reports ceased to be available on 4 July 1940 but Greek reports were relayed until 27 October 1940 when broadcasts in International Code ceased.

The suspension of the Malta Fleet Synoptic message on 7 July 1940 caused the loss of valuable information to Gibraltar. Consequently, special forecasts in Fleet Synoptic form for the areas westwards of Malta to 5° E. longitude were prepared on the 0700 and 1800 G.M.T. charts and cabled to Gibraltar until February 1941 when the preparation and broadcast of Fleet Synoptic messages reverted to Malta.

With the setting up of H.Q., British Air Force, Greece, reports from Greek stations began to be distributed on inter-Command channels in December 1940. In the same month, Athens (SXA) broadcasts were recommenced but in British cypher. Malta again relayed Greek reports to London from 7 April until 21 April 1941 when, with the fall of Greece, broadcasts ceased. Crete reports were then relayed from 29 April until 14 May when those broadcasts also ceased.

In May 1942, a Combined Services cable channel was opened between Malta and Alexandria, the Malta terminal being within the R.A.F. underground H.Q. at Lascaris. This enabled all but ' Top Secret ' traffic for Alexandria and Almaza to be transmitted uncyphered. Messages of ' immediate ' priority were cleared within an hour.

Technical Problems

These were similar to those which arose in the United Kingdom. The difficulty should be mentioned, however, of forecasting accurately at Malta the occurrence of the high level instability with which thunderstorms are often associated in the Western and Central Mediterranean, especially in the spring, and also the occurrence of dust haze in the upper air due to the effect of dust raising winds and duststorms in North Africa. Lack of data precluded any effective research on these phenomena before or during the war.

CHAPTER 23

WEST AFRICA, EAST AFRICA AND WESTERN INDIAN OCEAN

West Africa

Growth and Development of the Service

A network of meteorological stations had been maintained in the four British West African Colonies before August 1935. The observations were mostly limited to one daily and were made by staff of the Agricultural and Medical Departments ; there was no forecast service. When Imperial Airways opened a weekly air service between Khartoum and Kano, a meteorological service was organised for aviation between Fort Lamy and Kano. It included a broadcast of Nigerian observations from Lagos, a forecast centre at Kano, a system of point-to-point communications and the transmission of meteorological information to aircraft in flight. When the air service was extended to Lagos in October 1936, a similar organisation was put into operation between Kano and Lagos.

It was proposed in 1937, to form a combined British West African Meteorological Service, with headquarters in Lagos and subsidiary offices at Accra, Freetown and Bathurst. The cost of the organisation in each colony was to be borne by the appropriate Government, and the Governments of the Gold Coast, Sierra Leone and Gambia undertook to contribute towards the cost of the H.Q. organisation at Lagos. Civil aviation in West Africa did not, however, develop as expected and at the beginning of the war, the meteorological organisation had not developed beyond the minimum requirements formulated in 1937. In fact, in certain Colonies, the proposals had not been fully implemented and the ideal of a combined British West African Meteorological Service was never really attained before the war, the service consisting of four Colonial organisations with little co-ordination.

Soon after the outbreak of war, additional meteorological facilities became necessary in West Africa in order to meet operational requirements. In September 1939, the Air Ministry sent meteorological personnel to Freetown in order to provide the meteorological information required by the Africa Station of the Fleet. In August 1940, Meteorological officers of the Royal Air Force Volunteer Reserve accompanied the personnel for the opening of an R.A.F. station at Takoradi, in order to provide meteorological facilities there and to serve the reinforcement route to the Middle East ; additional meteorological officers were posted to Accra and Lagos to augment the service at these places. Meanwhile, in Nigeria four officers of the Education Service and three other officers were recruited to take charge of meteorological stations between Lagos and Maiduguri and to act as Airport Controllers at those stations. The meteorological staff at Accra and Freetown also acted as Airport Controllers in addition to supervising the meteorological work in the Gold Coast and Sierra Leone.

Thus towards the end of 1940, there were in effect three separate meteorological services in West Africa :—

(*a*) The original B.W.A. Meteorological Service.

(*b*) The Meteorological Service provided by the Air Ministry to reinforce the original service.

(*c*) An Airport Control Service which had become affiliated to the Meteorological Service.

The above improvised organisation was unsatisfactory and inadequate to meet operational requirements in West Africa, particularly in regard to the ferry routes from North America and to the Middle East. It was felt that the Airport Control Service should be separated from the Meteorological Service so that meteorological personnel could give all their time to meteorology. Further, even with the additions of meteorological personnel which had already been made, the facilities available in West Africa were not adequate to meet operational requirements.

Accordingly, between November 1940 and February 1941, a Senior Officer of the Meteorological Office made a survey of the meteorological requirements in various parts of Africa and the Middle East. In the case of West Africa, it was proposed that the Air Ministry should assume control of the Meteorological Service and bear the cost of the additional organisation required for operational purposes ; the basic organisation of reporting stations and observations was to remain unchanged, and the Colonial Administration was to continue to bear the cost of this part of the service, and of any personnel of the existing service who remained engaged on work solely concerned with the supervision of meteorological stations or with the provision of observations. The proposals were agreed by the various authorities concerned towards the end of 1941.[1]

The essentials of the new organisation were as follows :—

(*a*) The Headquarters of the Meteorological Service was transferred from Lagos to Takoradi.

(*b*) Main forecasting and observing stations were established at Bathurst, Freetown, Takoradi, Lagos (Apapa) and Maiduguri with duties as follows :—

Bathurst : Provision of meteorological information for the Trinidad—Bathurst—United Kingdom delivery route, for the B.O.A.C. flying boat route United Kingdom—Lagos (Lisbon—Freetown section) ; and for R.A.F. units at Bathurst ; collection, dissemination and analysis of meteorological data from Gambia.

Freetown : Meeting meteorological requirements of the Fleet, Army and R.A.F. units at Freetown ; provision of meteorological information for the B.O.A.C. flying boat route ; collection, dissemination and analysis of meteorological data from Sierra Leone.

Takoradi : Administration of the Meteorological Service ; provision of meteorological information for the R.A.F. reinforcing route Takoradi—Khartoum (Takoradi—Lagos section) and for B.O.A.C. and Sabena services Takoradi—Lagos ; dissemination and analysis of meteorological data from stations in the whole of British West Africa.

[1] A.M. File S.90351.

Lagos : Provision of meteorological information for R.A.F. reinforcing route (Lagos—Kano section) ; for B.O.A.C. flying boat route (Lagos—Freetown section) ; for B.O.A.C. service Lagos—Kano ; for Sabena service Takoradi—Lagos—Douala ; for B.O.A.C. route Lagos—Libreville, etc. ; collection, dissemination and analysis of meteorological data from stations in Nigeria.

Maiduguri : Provision of meteorological information for R.A.F. reinforcing route Kano—Maiduguri—El Geneina and for B.O.A.C. service Takoradi—Lagos—Khartoum (Kano—El Geneina section).

(*c*) All the above centres were equipped with W/T receivers for the reception of meteorological information from neighbouring territories.

(*d*) The network of reporting stations particularly in Nigeria and the Gold Coast was increased.

During 1942, the organisation described above was steadily expanded to meet the growing and changing commitments. The chief changes were :—

(*a*) *Kano* became a forecast centre as it was frequently used as a night stop on the West Africa—Middle East route.

(*b*) *Accra* became a forecast centre as it was one of the termini of the South Atlantic Ferry.

(*c*) Subsidiary meteorological offices were opened at Ikeja near Lagos, Hastings, Waterloo and Jui near Freetown. Waterloo was used initially by Pan-American Airways (P.A.A.) who provided equipment and observers.

(*d*) The staffing of several reporting stations in Liberia was approved because Robertsfield and Fisherman's Lake had become termini of the South Atlantic ferry route. (Actually most of the reporting stations in Liberia were manned by the United States Army Air Force (U.S.A.A.F.) using British equipment initially.)

(*e*) The opening of the southern delivery route Yola—Makurdi—Fort Archambault—Nyala—El Fasher—Khartoum necessitated the opening of offices at Yola and Makurdi, but this route was closed at the end of 1942.

(*f*) The recruitment of a considerable number of African observers in Nigeria and Gold Coast was authorised so that many of the reporting stations in these colonies could be put on a 24-hour basis. P.A.A. and U.S.A.A.F. were also authorised, under certain conditions, to open reporting stations where they required them for operational purposes.

The improvement in the network of observations was necessitated by the method used for delivering aircraft ; most of the aircraft from the assembly base at Takoradi were flown to the Middle East in convoys of about five aircraft, each convoy having a leading aircraft which was the only one with a navigator ; visual contact with the leader was essential and blind flying in cloud of any appreciable extent was impossible. A high standard of forecasting was therefore demanded.

Representations from the Resident Minister regarding the inadequacy of the meteorological organisation in West Africa, resulted in another survey of the situation being made between December 1942 and February 1943. The principal effects of this survey on British West Africa were as follows :—[1]

(*a*) The Air Ministry assumed complete control of the meteorological organisation in British West Africa.

(*b*) An establishment to cover the following forecasting centres was approved :—

Headquarters (moved from Takoradi to Freetown).
Bathurst with subsidiary at Jeswang.
Freetown with subsidiaries at Waterloo and Jui.
Takoradi.
Accra.
Ikeja.
Apapa.
Kano.
Maiduguri.
Robertsfield (Liberia).
Harper.
Fishlake.

(*c*) In addition, establishments were agreed for forecasting centres at operational stations in French territory viz :—

Port Etienne.
Pointe Noire.
Abidjan.
Libreville.
Banana.
Douala.
Dakar.

(*d*) Measures to co-ordinate the R.A.F. and U.S.A.A.F. meteorological services, including the establishment of a combined R.A.F.–U.S.A.A.F. Central Forecasting Office in West Africa, were agreed.

(*e*) Meteorological Flights were established at Freetown, Lagos and Maiduguri.

(*f*) A communications organisation was approved involving the broadcasting at fixed times of collective messages from Lagos, Accra, Freetown and Bathurst, followed by a combined West African collective message from Accra on high power, and a second main collective from Bathurst for reception at Trinidad, New York, Gibraltar, Lisbon and United Kingdom.

(*g*) Certain recommendations were also made for the improvement of the meteorological services in Northern French Equatorial Africa, Cameroons, Gaban and Middle Congo.

This service was designed to meet not only the operational requirements already described, but also the requirements of an intensive anti-U-boat campaign from R.A.F. bases at Port Etienne, Dakar, Bathurst, Freetown, Fisherman's Lake, Robertsfield, Takoradi, Lagos, Libreville, Pointe Noire and Banana. The extent of the sea area for which meteorological cover had to be provided may be gauged from the fact that the length of the West African

[1] A.M. File S.90351.

coast-line between Port Etienne and Banana is roughly 3,700 miles. The relatively short endurance of the available aircraft called for highly accurate forecasting and the lack of reports from the South Atlantic Ocean area made it very difficult to provide adequate meteorological protection, particularly during the disturbed conditions (squalls) preceding the south-west monsoon and during the monsoon season itself.

Co-operation with Allied Meteorological Services

The acute staff shortage made it impossible for the Meteorological Office Air Ministry, to man all the stations listed above. The implementation of the organisation depended on the co-operation of a number of other interested authorities.

United States Services : In British West Africa proper, most help came from the United States authorities, whether they were Pan-American Airways, or United States Army Air Forces.

In 1941, Pan-American Airways opened air services from Takoradi to Khartoum, from Lagos to Bathurst, and from Lagos to Brazil via Monrovia. Forecasting for these services was done mainly by the British West African Service but gradually two other meteorological services were developed by the U.S.A.A.F. and P.A.A. At first all three meteorological services were concerned with the air traffic involved in the delivery of lease-lend material from South America to Middle East, but the scale of operations changed abruptly when normal air communications between the U.S.A. and the Far East were severed by the fall of important Pacific bases to the Japanese, and an alternative route via West Africa and India had to be operated. The 19th Weather Region of the U.S.A.A.F. were made responsible for the meteorological protection of the large flow of American aircraft to the East from South America to Liberia and Accra (via Ascension), and to the North from South America to Bathurst, Dakar (later) and Freetown. The full scheme planned by the U.S. authorities for meteorological facilities in the West African region and immediately surrounding territories was :—

Main stations at	Robertsfield (Liberia).
	Accra.
	Kano.
	Pointe Noire.
	Leopoldville.
Subsidiary stations at	Maiduguri.
	El Geneina.

This scheme was eventually combined with the British plan mentioned above and the final organisation consisted of forecasting centres at :—

Bathurst and Jeswang (British).
Freetown, Waterloo and Jui (British).
Takoradi (British).
Accra (Combined British and U.S.A.A.F.).
Ikeja (Combined British and U.S.A.A.F.).
Apapa (British).
Kano (Combined British and U.S.A.A.F.).
Maiduguri (Combined British and U.S.A.A.F.).
Robertsfield (U.S.A.A.F.).
Harper (U.S.A.A.F.).
Fishlake (U.S.A.A.F.).

British and American Meteorological Liaison Officers were stationed respectively at Accra, the Headquarters of the 19th Weather Region, and at Freetown, the British Air and Meteorological Headquarters.

In addition to their meteorological stations in West Africa itself, the U.S.A.A.F. had a main meteorological station at Ascension and helped to maintain a 24-hour observation and upper wind station at St. Helena. They also maintained radio-sonde stations at Kano, Accra, Ascension, Robertsfield, Dakar (later) and a radio-wind station at Robertsfield.

The very complete system of communications established by the American Army Communications Service (A.A.C.S.) was fully used; in fact the meteorological organisation for the South Atlantic ferry and reinforcement routes was operated very largely by means of these communications, the main meteorological stations on the African side for the transmission of synoptic and other data to America being Robertsfield and Accra.[1] The British meteorological station at Bathurst was concerned more with the operation of the B.O.A.C. South Atlantic Service (winter) to Trinidad and later with the R.A.F. ferry service from Natal.

French Equatorial Africa : French Equatorial Africa played an important part in the operation of the reinforcement routes from West Africa to the Middle East. On the Northern route, the French stations at Fort Lamy, Ati and Abeche were key stations and close liaison was maintained between the meteorological officers at Maiduguri and Fort Lamy. On the Southern route from Nigeria to the Sudan via Fort Archambault a British meteorological officer was for a short time stationed at Archambault. Schemes were drawn up for the improvement of the meteorological and communication facilities along this route, but before these could be made effective the route was placed on a care and maintenance basis. Later when operational bases were established at Pointe Noire and Libreville, British meteorological staff were sent there to act in a liaison capacity with the French Meteorological Service.

Assistance was also given by way of signals and meteorological equipment to enable the French authorities to maintain a basic service of reports and transmissions for the protection not only of the aircraft using the North and South reinforcement routes but also the civil aircraft operating between Nigeria and Douala, Libreville, Leopoldville and the Congo Valley to South Africa and the Nile.

Although General Leclerc authorised the attachment of a British meteorological officer to the Headquarters of the French Meteorological Service at Brazzaville, shortage of staff prevented this being effected, and liaison had to be confined to visits to Brazzaville by the Chief Meteorological Officer, West Africa, or an officer from Lagos or Libreville.

The Belgian Congo was another important area in connection with air transport routes to Middle East and South Africa. Although a reinforcing route through the Congo was surveyed, it was never used to any extent owing to the very great difficulties in its operation. Civil aircraft, however, operated through the Congo from Lagos to the Middle East and the South Africans operated routes through the Congo to North Africa.

[1] A.M. File S.64938.

In 1942, a Belgian meteorological officer, who was attached to Meteorological Office Headquarters, visited the Congo and a programme of expansion of the meteorological service was agreed between the British and Belgian authorities; a central forecasting station was established at Stanleyville; the number of reporting and pilot balloon stations was increased, and equipment sent for the opening of many more reporting stations as they became necessary. Meteorological broadcasts from Leopoldville were improved both as regards frequency and quality.

French West Africa : Following their change of allegiance to the side of the Allies, French West Africa, and to a lesser extent North Africa, assumed an important role in 1943 in regard to operations in British West Africa. Liaison with the French became necessary at the end of 1942 when a reinforcement route Kano—Algiers was operated for a time by the U.S.A.A.F. Later, many operational R.A.F. bases were established on French territory between Port Etienne and Pointe Noire. At Dakar, the Headquarters of the French Meteorological Service, a Combined Operations Room was established and a British meteorological officer was posted there for liaison duties with the French Meteorological Service. All possible help was given to the French to enable them to re-establish their pre-war organisation and the availability of the high power inter-continental collective issues from Dakar was of the utmost value for forecasting in West Africa and also for operations on the South Atlantic ferry routes from Natal in Brazil to Rufisque (Dakar), used by the U.S.A.A.F., and from Natal to Bathurst, used by the R.A.F.

Administrative and Technical Problems

The meteorological service in West Africa was difficult to organise, and co-ordination of technical procedure difficult to achieve, because three of the main meteorological stations had widely different functions. Bathurst was concerned primarily with long distance flights to Gibraltar, Lisbon and United Kingdom and across the South Atlantic to Trinidad and South America. The main function of the meteorological centre at Freetown was to co-operate with the Fleet and provide information for reconnaissance flights. Further east, Lagos and the other meteorological stations were primarily concerned with meeting the requirements of the reinforcing routes across Africa. The difficulties were accentuated by the relative shortness of the tour of duty in West Africa (18 months) and by the lack of reference books on forecasting in the area. Thus an officer who came from the United Kingdom was just beginning to acquire useful experience in tropical meteorology when he had to return home.

Little research had been done before the war into the problems of forecasting in the tropics and the shortage of manpower and apparatus precluded any extensive programme of research during the war. Nevertheless the basic problems of forecasting tropical weather conditions were common to all stations in the area and a great deal was written, and considerable progress made, regarding the explanation and forecasting of such phenomena as the advent of spells of Harmattan haze, the development and movement of the West Africa line squall and the seasonal distribution of weather over West Africa[1]. Much

[1] The relevant publications were S.D.T.M. 54 'Pressure Distribution and the Synoptic Chart in Central and West Africa', M.O.M.365/17 'The Takoradi—Khartoum Air Route', M.O.M.484 'Weather of the Sierra Leone Peninsula' and M.O.469 'Pilots Primer of West African Weather'.

remained to be done at the end of the war, particularly in connection with the problem of forecasting upper winds and in regard to the nature and behaviour of the inter-tropical convergence zone. Close collaboration between meteorological officers and aircrews resulted in the former receiving much valuable information relating to flying under monsoon conditions and also many excellent photographs of clouds and squalls. Much of this information was incorporated in M.O.M.477 'Flying in Cumulo-Nimbus Cloud' which was written by the British West African Meteorological Service.

East Africa and Western Indian Ocean

The war-time meteorological organisation in East Africa fell into two main phases, the first until the Air Ministry assumed control in January 1943 and the second from then until the end of the war.

Although East Africa was only slightly affected by war activities, there were three distinct operational phases :—

(*a*) the East African campaign following Italy's entry into the war in 1940;

(*b*) the Madagascar campaign in 1942;

(*c*) the anti-submarine measures in the Western Indian Ocean, developed during 1943–44.

Meteorological services for (*a*) and (*b*) were provided mainly by the British East African Meteorological Service (B.E.A.M.S.) and the South African Air Force Meteorological Service. The Meteorological Office was responsible for meeting the requirements for (*c*). Meteorological facilities were also provided for air transport services throughout the period.

Growth and Development of the Service

Until Italy entered the war in June 1940, the meteorological services in East Africa were provided entirely by the B.E.A.M.S. The Service was established on a temporary basis in 1929 primarily to make a climatic survey of East Africa. It was later made permanent, and a synoptic reporting network and forecasting service established, mainly to meet the needs of the Empire air services between Cairo and Capetown. The Director of the B.E.A.M.S. was assisted by six British meteorologists, the remainder of the staff, apart from a few European clerical and typing assistants, being Asian and African clerks and meteorological observers. Full-time observing staff were located at airfields and the more important reporting stations where they made synoptic and pilot balloon observations and made routine reports to the Central Forecasting Office in Nairobi five times daily; they also provided special reports for aviation purposes on request. Most reporting stations were manned by part-time native observers, usually District Commissioners' Clerks, controlled through territorial meteorological offices, each with a meteorologist in charge, at Dar es Salaam (for Tanganyika) and Kampala (for Uganda). All the forecasting, however, was carried out in the H.Q. office at Nairobi.

Reports from individual stations were received mainly over Post Office channels, by W/T, telegram or telephone, but these communications facilities were quite inadequate for an efficient synoptic reporting and forecasting service.

Cable & Wireless, Ltd., received synoptic messages from other areas and broadcast the East African collective meteorological messages under contract, but during the early part of the war, additional receptions were arranged through R.A.F. and Army Signals.[1]

Forecasts were provided before the war for a number of air transport services and for the general public, with special provision for the farming community. Throughout the war, the climatological and other non-synoptic services of the B.E.A.M.S. were maintained almost unchanged.

On Italy's entry into the war, the British East African territories, bounded on the north by Abyssinia and Italian Somaliland, were directly threatened with invasion, but later became the base for the successful campaign in Italian East Africa. The meteorological services in the field for this campaign were provided by the S.A.A.F. Meteorological Service; a considerable number of special reporting stations were established, and a senior S.A.A.F. Meteorological Officer was attached to combined Air Force Headquarters in Nairobi. Forecasts for the campaign were prepared in the Central Forecasting Office, Nairobi. As the war receded from East Africa during 1942 the S.A.A.F. meteorological personnel were gradually withdrawn. The S.A.A.F. had, for the first time, made a regular series of aeroplane ascents for the observation of upper air temperature at Nairobi, a most valuable effort which was later continued by a meteorological flight of the R.A.F.

In 1942, arrangements were made to send Air Ministry meteorological staff to East Africa to meet specific R.A.F. requirements, and a Senior Meteorological Officer was posted to H.Q. No. 207 Group (which later became Air Headquarters, East Africa) in Nairobi, to co-ordinate these requirements under the Chief Meteorological Officer, H.Q. R.A.F., Middle East. The Senior Meteorological Officer at H.Q. No. 207 Group was responsible for maintaining liaison with the B.E.A.M.S. Central Forecasting Office, and for other duties which included the provision of a meteorological office at Mombasa for R.A.F. flying boat operation, meteorological services and instruction at Nos. 70 and 72 O.T.U.s located respectively at Nakuru and Nanyuki, and supervision of the work of the R.A.F. meteorological flight at Nairobi. He was assisted by six meteorological officers, a number of assistants and airmen meteorologists as well as some airmen temporarily loaned by the Director of the S.A.A.F. Meteorological Service, until such time as sufficient R.A.F. personnel became available.

The Naval Meteorological Service gave considerable help to the Air Ministry Meteorological Office and to the B.E.A.M.S. Because of the Japanese threat in the Indian Ocean, the H.Q. of the C.-in-C. Eastern Fleet was withdrawn in 1942 to Mombasa, and the Fleet Meteorological Officer was attached to that Headquarters. Also in East Africa were a Naval Meteorological Liaison Officer and three Naval Meteorological Officers, attached to Royal Naval Air Stations who, with a number of naval ratings, were performing essential duties in the forecasting offices at Nairobi and Mombasa. The B.E.A.M.S., however, continued to prepare and issue by W/T the one daily Indian Ocean Fleet Synoptic message.

[1] A.M. File S.71254.

After the withdrawal of the South African meteorological personnel in 1942, there were still three separate meteorological services in East Africa, *i.e.*, the Air Ministry Meteorological Service, the B.E.A.M.S. and the Naval Meteorological Service. The liaison between them as regards day to day requirements was very close, but the arrangement was not satisfactory as regards administration and matters of policy. It was, therefore, proposed at an Air Ministry meeting on 1 June 1942, that the Air Ministry should assume control of the B.E.A.M.S. for the duraction of the war and should appoint as Deputy Director a senior meteorological officer of some years' standing, with the rank of wing commander. The Air Ministry assumed control of the B.E.A.M.S. on 18 January 1943, amalgamating it with its own meteorological service in East Africa. As it had been decided that all British meteorological persônnel overseas should be mobilised in the Meteorological Branch of the R.A.F.V.R., the Director, B.E.A.M.S. became Chief Meteorological Officer, East Africa, with the rank of group captain. He was directly responsible to D.M.O., Air Ministry. A senior meteorological officer from Air Ministry was appointed Deputy Director, with the rank of wing commander, and arrived in Nairobi on 10 February 1943. The Assistant Director, B.E.A.M.S., was commissioned with the rank of squadron leader and five B.E.A.M.S. officers were commissioned with the rank of flight lieutenant.

The Air Ministry having assumed control, steps were taken to remove the forecast section of the B.E.A.M.S. office to A.H.Q. East Africa, and the R.A.F. provided communications services, including increased and exclusive meteorological W/T facilities for receiving and sending directed and broadcast messages. The contract with Cable & Wireless Ltd. for receiving and transmitting meteorological data was then suspended in Aguust 1943. A new meteorological building was occupied in May 1943; it became the main forecasting and meteorological communications centre for East Africa and the Western Indian Ocean, and was also an administrative centre in conjunction with the office of the C. Met. O. in Nairobi.[1]

Services for Nos. 70 and 72 O.T.U.s

The training programme at these O.T.U.s involved many training flights over sparsely populated areas of Northern Kenya, for which forecasts were mostly prepared in the Central Forecasting Office and telephoned to the units. Unit meteorological officers gave briefings and meteorological instructions. The lack of weather reports from the flying areas greatly hampered the provision of adequate meteorological data for training flights, but a proposal in 1942 to post about 30 airmen meteorologists to a number of stations in the area in order to provide the reports was dropped because of the shortage of personnel. The position became acute early in 1943 and A.H.Q. East Africa, decided to set up a number of mobile meteorological W/T reporting units, manned by aircrew W/T operators awaiting their O.T.U. course, of whom there were considerable numbers in Kenya. Twenty such men were given the necessary training in meteorological observing and coding, and two of the mobile stations were set up in April 1943. Both O.T.U.s were later transferred from Kenya to the Middle East and the scheme for mobile meteorological reporting units was dropped.

[1] A.M. File S.82514.

The Defence of the Western Indian Ocean

When the O.T.U.s were transferred from Kenya, the main activities of the R.A.F. in East Africa moved to the Western Indian Ocean where plans for extensive anti-submarine defence measures were being implemented. Finally, three flying boat squadrons were based in the area, at Mombasa, Dar es Salaam and Diego Suarez, with a repair base at Kisumu. Advance bases were also set up on some of the islands, to which detachments or whole squadrons were moved to meet specific operational requirements. For a time also, in 1943, a squadron of Wellington aircraft was based at Mogadishu. Meteorological facilities were provided during 1943 and maintained at all these bases, at least one meteorological officer being allocated to each base. The main development, however, without which the increased meteorological services would have been largely ineffective, was the provision by the R.A.F. of a network of W/T channels exclusively for meteorological purposes, which linked A.H.Q. East Africa, with the main and advanced flying boat bases. A few inland stations handling a comparatively large number of transport air services were later brought into this network, the complete network of stations being :—

Nairobi (A.H.Q., E.A.)	Central forecasting and communications office; main synoptic broadcast.
Mombasa	H.Q. No. 246 Wing; main flying boat base; independent forecasting station.
Dar es Salaam	Main flying boat base; B.E.A.M.S. Territorial office for Tanganyika; independent forecasting station.
Lindi	Flying boat alighting area; reporting station.
Pamanzi (Comore Is.) ..	Advanced flying boat base; subsidiary forecasting station.
Diego Suarez	Main flying boat base; H.Q. No. 258 Wing; independent forecasting station.
Tulear (S. Madagascar)	Advanced flying boat base; independent forecasting station.
Seychelles	Advanced flying boat base; independent forecasting station.
Mauritius	Advanced flying boat base; independent forecasting station.
Mogadishu	Temporarily a base for Wellington squadron in 1943; subsidiary forecasting station; administrative centre for Somalia reporting stations.
Kisumu (Kenya) ..	Flying boat repair base; subsidiary forecasting station, mainly for transport aircraft.
Tabora (Tanganyika) ..	Subsidiary forecasting station, mainly for transport aircraft.
Kampala	B.E.A.M.S. Territorial Office for Uganda.

A system of three-hourly reports was brought into operation on this network,[1] a great improvement on the very limited reporting system available on account of poor communications. Weather reports from the stations were sent as

[1] One observation of the three-hourly series—the 2030 G.M.T. observation—was not made.

directed messages to A.H.Q. East Africa, and there broadcast in collective messages half an hour later. The messages were encyphered with one-time pads, copies of which, so far as available and having regard to geographical location, were held at the stations on the network. Besides providing more up-to-date and regular information for routine and operational forecasting, the increased number of reports gave forecasters a much improved picture of the diurnal variation of weather in the area, many features of which had hitherto been missed. It also led to the discovery of minor trough-like disturbances, moving in a westerly direction in the S.E. trade wind, which, together with the inter-tropical 'front' or convergence zone, formed the basis of the system of analysis which was introduced during this period.

The number of daily meteorological broadcasts from Nairobi also increased considerably. In addition to the collective messages mentioned above, which were entirely for use within the East African meteorological organisation, the number of general synoptic broadcasts of East African observations for the use of neighbouring services was increased from two to five. Also, three daily collective messages consisting of selected reports from stations in the Middle East, the Sudan, Aden area, Rhodesia, South Africa, Madagascar and India, plus three daily broadcasts giving forecasts, analyses and a general appreciation covering East Africa and the Western Indian Ocean, were introduced for the benefit of the East African forecasting stations.

The regular synoptic reports were supplemented by in-flight and post-flight weather reports from flying boats on routine and operational flights. On certain occasions, special meteorological reconnaissance flights were authorised, on meteorological advice, especially during periods of cyclone activity. The three-hourly reports and the additional reports which it became possible to obtain at short notice, proved of great value in following the progress of cyclones. The meteorological W/T network also enabled a new procedure for the issue of cyclone warnings to be put into operation, so that flying boats could withdraw from threatened bases in good time.

Enough officer staff were usually available to meet commitments, but there were sometimes acute shortages of ancillary staff. The difficulties were largely overcome by employing Italian prisoner-of-war ex-meteorological personnel, after the surrender of Italy in 1943.

Services for Transport and Civil Flights

The amount of regular air traffic in the East African Territories was never very great, but regular services were operated by B.O.A.C., the R.A.F. and the S.A.A.F. The first two operated flights on once-or-twice weekly schedules to Durban, Johannesburg, Madagascar, Mauritius, Seychelles and Ceylon, Aden Khartoum and Cairo, Stanleyville, as well as shorter flights within British East Africa. The S.A.A.F. flights were mainly on the Cairo—Johannesburg shuttle service which increased to ten or more daily in each direction during the repatriation of South African personnel from the Mediterranean area in 1945. During most of the war, the requirements of the transport and civil flights were met by the meteorological office at Eastleigh (the main airfield for Nairobi) which acted as a distributive station, forecasts being supplied by the meteorological section of A.H.Q. East Africa, in Nairobi, but from December 1944, a main forecasting unit was provided at Eastleigh.

Upper Air Information

A network of pilot balloon stations which had been maintained by the B.E.A.M.S. continued throughout the war to supply upper wind information which was supplemented by observations from the additional island stations set up from 1943 onwards. From August 1943, the radar method of wind finding was operated at Mombasa, the radar facilities being made available by the Army; observations continued until the middle of 1945.

Although a series of ascents had been made by the S.A.A.F. at Nairobi, information regarding upper air temperature was not regularly available in East Africa until No. 1414 Met. Flight was formed at Eastleigh (Nairobi) in May 1942 and maintained an extremely regular series of flights until the end of the war, operating successively with Gladiator, Hurricane and Spitfire aircraft. Detachments of this flight operated for short periods at Mombasa, Nakuru and Nanyuki, and from August 1943 to April 1945 at Mogadishu, making two ascents daily with great regularity at the latter place. No. 1568 Met. Flight was formed in May 1943 and operated with Hurricanes at Diego Suarez until August 1945, with a detachment at Tulear from July 1943 to April 1945. No. 1569 Met. Flight was formed in June 1944 in Mauritius and operated until June 1945. To meet special requirements, such as those of the intensified S.A.A.F. Cairo—Johannesburg transport service in 1945, a detachment of No. 1414 Met. Flight operated for varying periods at Kisumu, Tabora and Soroti (Uganda), also at Mombasa.

Apart from their value in connection with daily forecasting, these flights gave considerable insight into meteorological conditions in the upper air in a part of the world where little was known. The upper air temperatures were also of value for the Meteor reports which were supplied daily for long periods during 1943–45 to artillery units by the meteorological offices at Eastleigh, Mombasa and Diego Suarez.

Instruction of R.A.F. Personnel in Tropical Meteorology

A series of short courses of lectures on the meteorology of tropical regions, with special reference to the western Indian Ocean, was given in 1944 at A.H.Q. East Africa to a number of flying boat crews newly arrived from the United Kingdom. A booklet on 'Weather of East Africa, Madagascar and the Islands Area' written in non-technical language for flying personnel was prepared and printed in the meteorological section of A.H.Q. East Africa; it contained a slightly modified version of an account of tropical cyclones which had been prepared in the B.E.A.M.S.

Development of Meteorological Services in Adjacent Territories

Somalia: The expulsion of the Italians from Somalia in 1941 left that territory without a meteorological organisation, and the Chief Meteorological Officer, East Africa, became responsible for restoring a network of synoptic reports in what had been Italian Somaliland.[1] Early in 1943, a meteorological officer was posted to Mogadishu, where there was already a small R.A.F. unit, to resuscitate the reporting service. For a few months, this officer also assumed

[1] A.M. File S.55403.

the duties of Commanding Officer of the unit. A number of native observers were recruited and given training, which included a course in English, and in the latter part of 1943 six synoptic reporting stations, including two pilot balloon stations, were in operation. Reports were sent by Army signals channels to Mogadishu, thence to Nairobi by W/T, and were included in the general Nairobi collectives. The reporting stations were inspected at intervals. A.H.Q. East Africa providing an aircraft for the purpose.

Madagascar : When France fell in June 1940, Madagascar came under the control of the Vichy Government, and the synoptic reports and collective messages ceased although the meteorological service remained in being. When Allied Forces entered Madagascar in 1942, meteorological requirements became the responsibility of the Director of Meteorological Services, S.A.A.F. The collective synoptic messages were restored, the encyphering being done by S.A.A.F. meteorological personnel posted to Tananarive for the purpose. No attempt was made to provide a forecasting service then, but the development of flying boat operations in 1943 made it necessary to provide forecasts at the three bases in the area, Diego Suarez, Tulear and Pamanzi. The S.A.A.F. meteorological personnel were then being withdrawn and the forecasting service in Madagascar became an Air Ministry Commitment.

In order to tide over a period of temporary staffing difficulties, the Director of the S.A.A.F. Meteorological Service agreed that a number of his personnel could be retained in Madagascar until the end of 1943, by which time the necessary R.A.F. meteorological office staff would be available in the East African area. As no airman meteorologists were available from R.A.F. sources, it was decided to employ French militarised personnel. A number of these men were enrolled and trained and were then posted to the new forecasting stations. This arrangement worked satisfactorily until the stations were closed at the end of the war.

During the early stages of co-operation with the Madagascar Meteorological Service, a R.A.F. Meteorological Liaison Officer was stationed in Tananarive and for a short time he also acted as R.A.F. Liaison Officer to the British Military Mission there. For a time, the East Africa and Islands synoptic reports were sent to Tananarive in special messages from A.H.Q. East Africa, using a one-time pad cypher, but the Air Ministry later agreed that the Director of the Madagascar Meteorological Service should hold the general cyphers so that these messages were no longer needed.

Indian Ocean Islands : Increased or new meteorological facilities were also provided at some of the smaller islands of the western Indian Ocean in connection with flying boat operations. At Mauritius a local meteorological service under the Director, Royal Alfred Observatory, already existed and issued short synoptic messages and forecasts for H.M. Ships. The service was, however, too limited to meet R.A.F. needs and in June 1943 an Air Ministry forecasting unit was set up at the flying boat advanced base at Tombeau Bay and was strengthened by locally recruited assistants. The unit was later moved to the R.N. Air Station at Plaisance on the opposite end of the island and, for a time, the joint meteorological service was provided by R.A.F. and R.N. personnel. In 1944, however, the Naval Meteorological Service was withdrawn from Mauritius. Close liaison was maintained between the R.A.F. Meteorological

Officer and the Director, Royal Alfred Observatory, particularly in connection with the issue of cyclone warnings, although for operational purposes these were entirely the responsibility of the R.A.F. Meteorological Office. The messages for H.M. Ships formerly issued from Mauritius were incorporated in the more general Indian Ocean Fleet Synoptic issued from A.H.Q. East Africa.

In the Seychelles Islands, a meteorological reporting service already existed, under the control of the Director B.E.A.M.S., but helped financially by the India Meteorological Department. A forecasting office with a R.A.F. Meteorological Officer and locally recruited assistant staff was opened in June 1943 in the R.A.F. and R.N. combined operational headquarters. This office provided forecasts for flights to Ceylon and Aden as well as for operations from Seychelles. At the same time as the forecasting office was opened, the reporting station was moved from Port Victoria Pier to the top of Signal Hill (1,300 feet), primarily to improve the observation of pilot balloons which had been impeded by hills at the old site but, as there was some improvement in the supply of upper wind data and as the site was unrepresentative of conditions on the flying boat alighting area, it was abandoned in 1945.

To cover the wide gap between Seychelles, Mauritius and Diego Suarez, the Naval Meteorological Service had, for the cyclone season 1942–43, posted a meteorological officer and naval ratings to Agalega Island to set up a reporting station with W/T facilities. The receipt of these reports in Nairobi was, however, very irregular, and the station was closed in March 1943. The C.Met.O. East Africa sought Air Ministry help for the following cyclone season, and sanction was given for the manning of the Agalega station until May 1944. For this purpose, local staff were recruited in Mauritius, one being proficient in maintaining W/T equipment. All were trained in meteorological observing, pilot balloon work and R.A.F. W/T practice. The necessary instruments and a W/T set provided by the R.A.F. were sent from Nairobi. The station operated successfully throughout the 1943–44 cyclone season and in 1944–45. Air Ministry sanction was also obtained for 1944–45 for a similar station on the island of St. Brandon. Each station provided seven reports daily, and special reports on request, as well as regular pilot balloon observations. Vital information was provided during periods of cyclone activity and the first indications of cyclones were sometimes given by the reports from one or other of these stations, under the administration of the Meteorological Officer, Mauritius. Much of their success was due to the co-operation of the Agalega Co. (Mauritius), particularly in shipping supplies to Agalega and providing office and living quarters on the island.

Liaison with the Naval Meteorological Service

Close liaison with the Naval Meteorological Service was maintained throughout the war. The R.A.F. Meteorological Office at Nairobi initiated cyclone warnings for shipping as well as for aviation and also prepared and broadcast the East African Fleet Synoptic messages which, on 1 January 1945, were increased from one to two daily. Naval meteorological officers shared full forecasting duties at A.H.Q. East Africa and Mombasa, and ancillary duties at those stations were carried out by naval ratings. For a while, the personnel of the two services operated a combined unit in Mauritius.

Technical Problems

Problems included those common to other tropical areas, namely the relation between wind and pressure distribution in low latitudes, the properties of the inter-tropical 'front' or convergence zone and the formation and behaviour of tropical revolving storms (variously known as cyclones, hurricanes and typhoons). Because of the orography of the East African Territories, there was also the problem of the effect of high ground on the stability of the air, on upper level pressure distribution and on wind flow. Little work had been done on these problems before the war, but, with the more severe demands made on the meteorological service during the war, and with the increased information which became available, considerably more attention was given to the problems both in the tropical operational areas and at Meteorological Office H.Q. In 1945 and 1946, the investigations required were summarised in M.R.P. 259 and 311 respectively. Dr. A. G. Forsdyke, who was posted to East Africa during the war as Deputy Director, B.E.A.M.S., spent much time in studying these problems, and in M.R.P. 318, published shortly after the war, he summarised 'The Present Position of Weather Forecasting in Tropical Regions'. In this paper, he showed that much work remained to be done and he listed items requiring investigation.

CHAPTER 24

INDIA, CEYLON AND SOUTHERN ASIA

On the outbreak of war, R.A.F. stations existed in N.W. India only—at Karachi, Ambala, Lahore, Risalpur, Kohat, Peshawar and Miransah—with Air H.Q. at Delhi or Simla. Civil air lines used the main Trans-India route, Karachi—Delhi (Rajsamand for flying boats)—Calcutta, with subsidiary routes Karachi—Ahmedabad—Bombay, Delhi—Bombay, Bombay—Poona—Madras, and Madras—Ceylon. The India Meteorological Department (I.Met.D.) maintained an administrative H.Q. and Central Forecasting Office at Poona which supplied information for the peninsula. I.Met.D. forecasters were stationed at Karachi and Peshawar to meet R.A.F. requirements and covered the area north of a line Ahmedabad to Allahabad. A British meteorological officer with the R.A.F. was also located at Peshawar and seconded to the Indian Government, civil forecasting centres at Calcutta covered the area Allahabad to Akyab, at Delhi the area Jodhpur to Allahabad and at Karachi the area Jodhpur to the Persian Gulf. A forecast centre at Rangoon (Burma Meteorological Service) catered for the route Akyab to Victoria Point where it handed over to the Malayan Meteorological Service for the route to Singapore. The total officer strength of the I.Met.D. in 1939 was about 40 of whom only about 20 were forecasters.

The Colonial Government maintained a small meteorological service in Ceylon manned entirely by Ceylon personnel. There was no forecasting organisation but there was a reasonably good network of reporting stations. These reported to Colombo daily at 0300 G.M.T. but the information was used for climatological work and was of little use to aviation.

In Malaya the Colonial Government maintained a meteorological service with a headquarters and forecast section manned by British personnel at Singapore.

Synoptic reports were collected at Poona, Karachi, Delhi, Calcutta, Rangoon and Singapore chiefly by land-line (telegram), and each centre broadcast collectives by W/T on civil aviation transmitters on short wavelengths. Although these were suitable for distant reception they were unreliable for internal use. A Fleet synoptic meteorological message was broadcast by W/T from Bombay. At Poona two main synoptic charts for the whole of India were prepared daily for 0800 and 1700 local time. Other forecast centres had to be content, because of financial considerations, with reports from smaller areas. Broadcasts from Iraq were received at Peshawar and Karachi by R.A.F. signals.

Point-to-point W/T communications were available between R.A.F. stations and between airfields on the civil air routes; both were used to distribute forecasts to stations which had no forecasting office. Forecasts for the various

sections of the Trans-India route were issued twice daily to all landing grounds together with a selection of three-hourly reports and upper winds; a senior assistant was available for consultation. At Singapore information was also supplied for the route to Australia.

Expansion during the period 1940–1942

India: Initial R.A.F. planning was mainly directed to North-West India and, until 1940, there was no discussion on increasing or modifying meteorological services. In the summer of 1940 a conference of representatives of Air H.Q., I.Met.D., Civil Aviation, Finance, etc., planned the development of an India Meteorological Reserve and its possible mobilisation as a field H.Q. together with mobile meteorological units, but the scheme was shelved and little development occurred during the year. The personnel of the meteorological office at Karachi, which met R.A.F. requirements, were moved to Lahore and the civil meteorological office at Karachi undertook forecasting for the R.A.F. in that area.[1]

The entry of Japan into the war in 1941 gave an impetus of war planning in India, and after the fall of Singapore it was arranged that Air Forces sent to Burma would use the forecasting facilities at Rangoon. Various bases in the Calcutta area and on the east coast of India were earmarked for meteorological services but little was done to provide personnel or equipment.

Air H.Q. Bengal with No. 221 Group was set up in the Calcutta area early in 1942.[2] The need for meteorological services became pronounced and in May the provision of a meteorological section of Air H.Q. Bengal with one forecaster was approved; this was set up on a civilian basis by I.Met.D. Approval was also given for expenditure on four lorries and other equipment for mobile units to be organised by I.Met.D. while personnel problems were to be solved on the lines of the Air H.Q. 1940 conference. At this stage a R.A.F. Meteorological Officer arrived at Air H.Q. but apart from the supply of the lorries little else materialised due to the absence of any firm directive. In March and April a Chemical Warfare Mission visited India from United Kingdom and made known their meteorological requirements at a conference in Delhi; it was recommended that the 1940 plan should be implemented, that the R.A.F. Meteorological Officer at Peshawar should take an appointment at Air H.Q. and form an Air H.Q. Meteorological Section and that an I.Met.D. Liaison Officer should be appointed with him. The two appointments were effected during May and June. Air H.Q. directed on 3 July that plans should be prepared for an increased meteorological service to be co-ordinated with known plans for the expanded Air Forces in India. The plans were to include a mobilised element consisting of R.A.F. and I.A.F. personnel (the latter to be commensurate with the envisaged post-war strength of I.A.F.) adequate for the needs of units planned for the Calcutta area and to the east.

Plans were duly prepared, approved by Air H.Q. and financial authority given by the India Government. Provision was made for the following units:—

[1] A.H.Q. India File 117/4/Air/1.

[2] A.M. File S.82012.

Type and Numbers of Unit	*R.A.F.V.R.*	*I.A.F.*	*I.Met.D.*
9 Main Forecasting Centres	A.H.Q. Bengal H.Q. No. 221 Group H.Q. No. 222 Group	H.Q. No. 225 Group	H.Q. No. 223 Group H.Q. No. 227 Group H.Q. No. 226 and Karachi, Delhi, Calcutta.
42 Subsidiary Forecasting Centres.	12	5	25
36 Distributive Centres ..	8	5	23
45 Reporting Units ..	15	10	20
5 Mobile Units, Forecasting.	3	2	—
5 Mobile Units, Reporting	4	1	—
10 Pilot Balloon Stations	1	1	8

This involved the provision of some 100 forecasters and 800 assistants for the I.Met.D. and I.A.F. and 47 officers and 220 other ranks for the R.A.F.V.R. (Meteorological Branch). The I.Met.D. were authorised to set up training schools at Poona and it was arranged to commission for meteorological service with the I.A.F., both experienced meteorologists of the I.Met.D. and trainees. On the R.A.F. side, permission was given to remuster to meteorologist suitable R.A.F. airmen in other trades, and the proposed establishment of the R.A.F. Meteorological Service in India, as approved by Air H.Q., was communicated to the Meteorological Office, Headquarters, Air Ministry.

In July 1942, D.M.O. sent a senior meteorological officer to Air Headquarters, India to advise in liaison with the Director-General of Observatories, I.Met.D. (D.G.O.) on the meteorological organisation required for the R.A.F. and Army. He recommended that:—

(i) A Chief Meteorological Officer (C.Met.O.), India should be appointed with the rank of Group Captain.

(ii) All R.A.F. meteorological personnel in India should be in uniform and adequately trained.

(iii) A stiffening of experienced British meteorological officers should be provided, particularly at Group Headquarters.

(iv) Special meteorological radio and teleprinter channels should be provided.

(v) Equipment for 50 surface and upper air stations should be supplied.

It was decided in September that while the existing meteorological organisation in India would continue under D.G.O., a Chief Meteorological Officer with the rank of Group Captain should be appointed to administer the meteorological sections of the Air Forces and Army. He would work closely with the civilian organisation to secure the most efficient service. A Chief Meteorological Officer was selected in December 1942 and Air Ministry agreed in January 1943

that 28 officers and 122 airmen should be posted to India provisionally pending an examination of staff requirements by the Chief Meteorological Officer after his arrival in India.

By the end of 1942 I.Met.D. staff had increased sufficiently to allow a 24-hour forecast watch at the following centres :—Air Headquarters, Bengal (Calcutta), Headquarters No. 221 Group (Calcutta), New Delhi, Karachi and Headquarters No. 225 Group (Bangalore). Meteorological sections of Headquarters No. 223 Group (Peshawar) and Headquarters No. 227 Group (Lahore) were also partly manned. New forecast centres were opened in East Bengal at Headquarters No. 224 Group and at the R.A.F. Madras Wing Headquarters; also a mobile meteorological unit was attached to the Army training camp at Deolali. A start was made to provide observations from selected stations at 06 and 12 I.S.T. for supplementing the charts for 09 and 18 I.S.T. Preliminary arrangements were also made for night observations so that charts could be prepared for 23 and 03 I.S.T.

To ensure the fullest possible co-ordination between the different services, D.G.O. moved his administrative section from Poona to New Delhi. The move was completed by 10 October 1942.

Ceylon : At the end of February 1942, one R.A.F. Meteorological Officer was posted to Trincomalee and early in March 1942 four officers of the Malayan Meteorological Service arrived in Ceylon. The preliminary work of providing a forecast service begun on 19 March 1942 and the first charts were drawn on 9 April 1942. The Senior Meteorological Officer went to Air Headquarters, India to discuss meteorological requirements in Ceylon with Air Staff and D.G.O. (I.Met.D.) and as a result a 24-hour forecasting service was started in Colombo on 9 May 1942. The meteorological section occupied an office adjacent to the G.R. Operations Room and forecasts were supplied to the Operations Staff of No. 222 Group and to R.A.F. stations at Colombo, Ratmalana and Katukurunda, to No. 990 (Balloon) Squadron, and to the Army and Navy in Ceylon. Subsidiary forecasting offices were also opened in 1942 at China Bay to serve the Eastern Area and at Koggala for the Southern Area.

During 1942 the frequency of reports from most of the 17 stations maintained by the Ceylon Meteorological Service was increased to five daily. These were supplemented by reports from the various R.A.F. stations, from 17 Wireless Observer Units and from the important island bases in the Indian Ocean, Diego Garcia, Mauritius, Seychelles, Rodriguez Islands, Cocos Islands and Addu Atoll. Arrangements were also made for upper wind observations from eight of the reporting stations for post-flight reports. The R.A.F. W/T station at Colombo instituted a twice daily collective broadcast which included reports from all the island stations and a selection of reports from Ceylon stations. Arrangements were also made to intercept at Colombo the W/T broadcasts from Karachi, Poona, Calcutta, Aden, Mauritius and Nairobi.

During this period the Navy had no forecast organisation in Ceylon and all forecasts were supplied by the R.A.F. Meteorological Service. A Naval Meteorological Officer, after setting up a Naval reporting station at Addu Atoll, was attached to the R.A.F. forecasting office to assist in the preparation of forecasts for the Navy in addition to carrying out his normal duties as Station Meteorological Officer, Colombo. Fleet forecasts and synoptic messages were prepared and broadcast twice daily by the Naval W/T station at Colombo.

Forecasts of weather conditions were supplied to the Army as required. The major requirement was the supply of data for ballistic corrections. The information was supplied by the Ceylon Observatory staff from data obtained by themselves or from data supplied from Colombo forecasting office. Meteor reports for artillery were supplied from Koggala and China Bay and arrangements were also made for members of the Ceylon Garrison Artillery to be trained with a view to forming two mobile meteorological units.

Joint Meteorological Commttee : The July 1940 conference at Air Headquarters had directed that the meteorological duties and work of the R.A.F., I.A.F. and I.Met.D. must be co-ordinated and that this could best be done by setting up a meteorological committee. This committee was formed in October 1942, under the chairmanship of D.G.O. The members included the Chief Meteorological Officer, Air Headquarters, and representatives of Air Headquarters, India and the I.Met.D. with the I.Met.D. Meteorological Liaison Officer at Air Headquarters as Secretary. Representatives of other India Governments and of the Fighting Services attended when subjects affecting them were under discussion. The Committee held nine meetings up to the end of 1942. The subjects discussed, and on which recommendations were made, included the priority of new meteorological centres, the training of meteorological personnel, codes and cyphers, meteorological flights and meteorological requirements for the Army.[1]

Exchange of Observations with Russia

Arrangements were made early in the war for an interchange of synoptic reports between the U.S.S.R. and the I.Met.D. These took the form of small special collectives which were broadcast twice daily from Tashkent covering stations in the Caspian Sea area and from Poona covering stations in N.W. India. Owing to unsatisfactory reception in both countries the results of the interchange were poor. Reception of Tashkent was particularly poor near the N.W. frontier, where it was most needed, particularly during winter. In order to improve reception in Russia arrangements were made in May 1944 to intercept the Poona transmissions at Delhi and retransmit them on a 15 Kw. U.S.A.A.F. transmitter. These transmissions proved more satisfactory and arrangements were accordingly made in September 1944 for the messages to be prepared in Delhi and broadcast over R.A.F. transmitters. This arrangement continued for the remainder of the war.[2]

Appointment of Chief Meteorological Officer, Air H.Q. India

The Chief Meteorological Officer took up his duties at A.H.Q. India on 14 February 1943. He was in charge of the R.A.F. Meteorological Service in India and was responsible for collaborating closely with D.G.O. who was ultimately responsible for the organisation of the Meteorological Service in India. The consequent division of duties between the I.Met.D. and R.A.F. Meteorological Service was discussed by the Joint Meteorological Committee in February 1943. It was decided to proceed on the lines already laid down except that Headquarters No. 225 Group would be staffed by I.Met.D. as an interim measure and the I.A.F. would be under the control of Chief Meteorological Officer; a priority list for the opening of forecast centres was drawn

[1] A.H.Q. India File 35/Met. [2] A.C.S.E.A. File A1/3100/Met. Part 1.

up. It soon became evident that the duties of the Chief Meteorological Officer, Air Headquarters, India, were to control the R.A.F. Meteorological Section, to recruit and control the I.A.F. R.A.F. Meteorological Section, to advise Air Staff on all meteorological matters affecting the R.A.F., liaison with I.Met.D. through the Joint Meteorological Committee and their Liaison Officer at Air Headquarters, liaison with Chief Meteorological Officer, Middle East and to provide climatological reports and data to the operational planning staffs.[1]

Expansion of Meteorological Facilities in 1943 and early 1944

The R.A.F.: At the beginning of 1943 the total strength of the R.A.F. meteorological section in India was 7 officers only. Reinforcements arrived gradually during the first half of 1943 and by September the total of officers had risen to 24; it remained at this figure for over a year. By arrangement with the I.Met.D. these officers were given special training in the meteorology of India at the I.Met.D. Central Forecasting Office at Poona. The position regarding airmen meteorologists was slightly better and showed a progressive increase to 70 by September 1944. Lack of personnel inevitably affected progress and only by integrating the use of R.A.F. and I.A.F. meteorological officers were forecast centres opened and maintained in the forward areas; but the number of such centres was always below the demand.

In the latter half of 1942, a R.A.F. meteorological officer had been appointed as liaison officer to the I.Met.D. forecast section of Air H.Q. Bengal. By June 1943, sufficient R.A.F. meteorological personnel had become available to take over this section from the I.Met.D. Two months later the I.Met.D. forecast section of H.Q. No. 221 Group Calcutta was similarly taken over. Meanwhile a requirement for a forecast section at H.Q. No. 224 Group Chittagong had arisen and could only be met by using I.A.F. meteorological personnel under a R.A.F. meteorological officer. The forecasting requirements of Nos. 221 and 224 Group H.Q. were chiefly concerned with the work of the R.A.F. in close support of the Army and with transport flights and supply dropping. In October 1943, Air H.Q. Bengal moved to Comilla and in December became H.Q. 3rd Tactical Air Force. H.Q. No. 221 Group moved to Imphal in December and for the ensuing year meteorological information was supplied by an I.A.F. meteorological section with an R.A.F. meteorological officer in charge. Meanwhile, a new Heavy Bomber Group (No. 231) had formed at Calcutta and it became necessary to provide a forecast section for H.Q. and meteorological units at the associated stations. The work of the Group was strategic in character and forecasts had to be supplied for operational flights as far afield as Rangoon, Indo-China, the Andamans and Malaya.

South East Asia Command (S.E.A.C.) formed at Delhi in November 1943, and a new Air Command S.E. Asia (A.C.S.E.A.) formed under the Supreme Allied Commander, Air H.Q. India remaining under the direct control of C.-in-C. India who in turn was responsible to the Government of India. The C.Met.O., who until then had been on the staff of Air H.Q. India as meteorological adviser to the Air C.-in-C., was transferred to the new Air H.Q. S.E. Asia. For some time the meteorological work for S.E.A.C. consisted in the preparation for the planners' reports. The Command moved to Kandy in April 1944, but it was not

[1] A.M. File S.82012.

until after C.Met.O. had moved with A.C.S.E.A. to Kandy in October 1944 that the work for S.E.A C really increased Later the Command became the Supreme Allied Command for South-East Asia (S.A.C.S.E.A.).[1]

A new formation, Eastern Air Command, formed at Calcutta on 15 December 1943, with operational control of U.S.A.A.F. and R.A.F. forces. This comprised the 3rd Tactical Air Force which included Nos. 221 and 224 Groups and certain tactical elements of the 10th U.S.A.A.F. Air H.Q. Bengal was absorbed into Eastern Air Command. It then became necessary to strengthen the meteorological organisation in the forward area and a Senior Meteorological Officer was posted to H.Q. 3rd T.A.F. to co-ordinate the work of the R.A.F. and I.A.F. meteorological units in the Bengal Assam area. He thus had effective control of the meteorological sections of Nos. 221, 224 and 231 Groups and of the units with the Army. Apart from the formation of further mobile units for the Army there was little or no expansion during the six months following April 1944.[2]

All meteorological units were formed as separate numbered units. This had considerable advantage as regards mobility, posting of both meteorological and signals personnel, welfare and the supply of equipment etc. There were, however, disadvantages. The meteorological officer had to devote more time than usual to administrative matters and was still dependent on other units for such items as transport. All units had to be attached to a parent unit for pay, rations, etc.

The I.A.F. Meteorological Section: It had been agreed that staff for a Meteorological Section of the I.A.F. should be recruited from staff of the expanding I.Met.D. and that the I.Met.D. should undertake the meteorological training of both officers and airmen. An establishment of 38 officers and 288 airmen had been envisaged in September 1942. By the beginning of 1943, one officer and seven airmen had been recruited and although the flow of officers steadily increased up to a total of 19 by September 1943, only 46 airmen had been recruited by September 1943. It was therefore decided in September 1943 to recruit suitable personnel direct and to open up a meteorological training school (I.A.F.) at Ambala as a section of No. 1 School of Technical Training.[3] As staff became available forecast centres were opened at Imphal (March 1943) Chittagong and Fenny (April 1943), Jessore (May 1943), Jiwani (June 1943) and Cuttack (September 1943), the first four providing meteorological information for operations and the last two for air routes.

The I.Met.D.: By the middle of 1943 the basic network of the I.Met.D. had expanded to some 280 reporting stations. In accordance with agreed policy, forecast centres were opened at Bhopal, Trichinopoly, Vizagapatam, Nagpur, Allahabad, Jodhpur, Chaklala, Ambala, Gwalior, Cochin, Hakimpet and Ahmedabad during the latter half of 1943 and at Risalpur, Jharsuguda, Quetta, Poona (Lohagaon) Yellahanka and Kolar during the first half of 1944.

Development of Regional Meteorological Broadcasts in India

Meteorological observations in India were reported mainly by telegram, the policy being to provide every main forecast centre with a telegraph office in or

[1] A.M. File S.96516/1.
[2] *See* Appendix No. 13 for the meteorological organisation in April 1944.
[3] A.M. File S.82012.

near the meteorological office but staffed by Posts and Telegraph personnel. The cost of telegraphic services was already high in 1942 and if the scheme had been extended with the planned expansion of the meteorological service the cost would have become excessively high. In any case it would not cater for the forecast centres in the forward areas which had to be mobile. The use of an all-India system of teleprinter channels was considered the ideal solution but was not practicable except as a long term policy. The alternative was to provide W/T transmitting stations solely for meteorological traffic with reception facilities at all meteorological offices, and a scheme was drawn up for a network of eight regional meteorological transmitters plus one central all-India W/T centre at Nagpur. The regional stations were to be located at :—

Outer Ring .. .. Karachi, Chaklala, Calcutta, Colombo.
Inner Ring .. .. Calcutta, Madras, Bombay, Delhi.
Central Transmitter .. Nagpur.

Weather reporting stations were to be grouped around each regional station to which they would report by telegram.[1] The resulting regional collective would be broadcast by W/T on two frequencies, received at Nagpur and rebroadcast by the central transmitter on six frequencies. Each forecast centre would be provided with two reception channels on which it could receive the whole of the Nagpur broadcast, whilst the standby reception channel would be available for reception of local regional transmissions or external broadcasts. The scheme was not ideal as, in a country nearly the size of Europe, all the regionals would not be heard everywhere, and as Nagpur could only rebroadcast one regional at a time a serious time lag was inevitable. However, it appeared the best short term plan based on the materials and manpower likely to be available. The matter was discussed at Air H.Q. India early in 1943 and it was agreed that one central and eight regional stations should be manned on a four-watch basis and 60 forecasting centres on a three-watch basis, and that the required manpower should be provided by March 1944.

The first regional broadcast station opened at Calcutta in May 1943 to cover the immediate requirements of the forecast centres forming in the forward areas. Karachi and Delhi became operative in December 1943. Subsequently there were delays in the provision of suitable equipment ; operators had to be recruited and trained ; and it was not until early in 1945 that the scheme as set out above was completed.

Liaison with Australia

After the fall of Singapore in 1942 there had been little or no meteorological contact with Australia but with the proposal in mid-1943 to institute a Ceylon—Australia Air Route, the S.Met.O. H.Q. No. 222 Group, Ceylon, visited Australia and arranged for an interchange of basic data and of pre-flight, in-flight and post-flight information. The organisation thus established remained in being with minor amendments for the rest of the war. It was similar to the M.O.O.F. organisation and consisted of the interchange by point-to-point W/T of synoptic data, analyses and advisory forecasts. It was arranged for special advisory forecasts to be exchanged for each flight, Colombo being responsible for the route from Ceylon to Cocos and Australia for the route Cocos to West Australia ; the forecast for the second part of the route plus the terminal

[1] A.M. File S.82508.

forecast received at the departure station would be incorporated in the final forecast for issue to the pilot, such forecast to be transmitted to the meteorological office serving the destination station.[1]

The organisation also included transmitting from the destination station for interception by the aircraft, a forecast for the second half of the route plus terminal forecast based on the latest available chart. The folder issued to the Captain of each aircraft included a synoptic chart, forecast form in zones, upper wind form and form for weather observations.

In order to augment the supply of upper wind data for this route Australia sent a small meteorological unit to the Cocos Islands in August 1943. This unit also took over the supply of weather reports by cable to Ceylon and Perth which had previously been undertaken by the staff of the Cable and Wireless Company.

The Allied Meteorological Committee South East-Asia (A.M.C.O.S.E.A.)

Towards the autumn of 1943, the advent of S.E. Asia Command and the expected development of the war South-eastwards from India made it clear to the Combined Meteorological Committee C.M.C. (a committee of the Combined Chiefs of Staff in Washington) that the time was opportune for a conference on the co-ordination of meteorological organisations in the S.E. Asia and adjoining theatres. The Indian Government was accordingly invited to send a representative to Washington ; C.Met.O. was selected and took part in a series of conferences during October 1943. Representatives of the U.S.A.A.F. Weather Service from India and S.W. Pacific, the Australian Meteorological Service, U.S. Navy and R.N. Naval Meteorological Services and the U.S. Weather Bureau were present. The following recommendations were made :—

(*a*) that an Allied Meteorological Committee should be set up for S.E. Asia ;

(*b*) that the necessary co-ordination of meteorological problems affecting India, China, S.E. Asia and adjacent theatres be achieved by meteorological committees or co-ordinating agencies in these theatres ;

(*c*) that certain proposed codes and cyphers should be used both for ground to ground and ground to air communication ;

(*d*) that arrangements be made for institution of synoptic reports from re-occupied areas and for their collection and broadcast ;

(*e*) that at least 10 sets of radio-sonde equipment be allocated for use in territories when re-taken from the enemy ;

(*f*) that existing radar facilities should be used for radio wind observations.

It was during the long series of meetings on codes that the U.C.O. form of code for weather reports in ground to air communication was first developed. By the end of the war this code was in use throughout a large part of the operational area.

The Allied Meteorological Committee S.E. Asia formed on 10 March 1944 with the following functions :—[2]

(*a*) Co-ordination of meteorological services for air forces, navies and armies in areas concerned, including co-ordination of synoptic and other airway reporting services.

[1] A.M. File S.82012. [2] A.M. File S.100160.

(*b*) Co-ordination of supply, distribution and maintenance of meteorological equipment in accordance with development programmes and operational requirements.

(*c*) Standardisation and use of common meteorological codes and cyphers.

(*d*) Recommendations concerning security and censorship matters.

(*e*) Liaison with various communication agencies regarding provision of communication and accessory services for meteorological purposes.

(*f*) Direct liaison as required with adjacent theatres and commands.

(*g*) Co-ordination with Combined Meteorological Committee in Washington.

Sir Charles Normand, then Director General of Observations (D.G.O.) was elected Chairman of the Committee and in addition to D.G.O. (I.Met.D.) the members included C.Met.O. (R.A.F.), Regional Control Weather Officer (R.C.O.) (U.S.A.A.F.) and the Fleet Meteorological Officer, East Indies Fleet (R.N.). After the retirement of Sir Charles Normand the Chairmanship was held in rotation at successive meetings by all the members. Meetings were held at approximately monthly intervals.

The more limited co-ordination between the R.A.F., I.A.F., and I.Met.D. Meteorological Sections continued to be effected through the Joint Meteorological Committee.

Reorganisation and Expansion to meet Operational and Air Route Requirements

By the middle of 1944 it had become evident that the increasing meteorological requirements could not be met without some drastic action ; not only was there a complete lack of reinforcements for the meteorological sections of the R.A.F., but the I.Met.D. and the I.A.F. meteorological section had not expanded as expected ; at some forecast centres the meteorological section did not enjoy that degree of confidence from aircrews which is so vital to full success. The C.-in-C. A.C.S.E.A. stated this in a visit to Air Ministry in February 1944, and proposals for remedying the position were sent to Air Ministry in July 1944. These included the manning by R.A.F. meteorological personnel of some 17 stations on the ferry routes, and the provision of personnel and signals equipment for ensuring up-to-date weather reports along these routes. The proposals were discussed at Air Ministry on 1 August 1944, and it was agreed that additional meteorological personnel should be provided for India with high priority. The proposals were also discussed with the Government of India and culminated in the suggestion of the Adviser to the Viceroy on War Administration (in consultation with A.C.S.E.A.) that D.M.O. should visit India to review and advise on meteorological organisation in India with special reference to the extension of participation by the Air Ministry Meteorological Office, *i.e.*, by R.A.F. personnel.[1]

The visit took place in October 1944, and, following discussions with the Government of India and the various Commands and a rapid tour of the various R.A.F., U.S.A.A.F. and I.Met.D. stations in India and Ceylon, the following arrangements were agreed :—

(*a*) The Meteorological Office would become responsible for all forecasting for the R.A.F. in India and for briefing of R.A.F. aircrews, the target date for implementation being March 1945.

(*b*) The I.Met.D. would remain responsible for the basic network of observing stations and for meeting the needs of civil aviation in India.

[1] A.M. File S.96516.

The above policy entailed the British service taking over control of some 27 forecasting offices from the I.Met.D. and a priority list for the order of change over was agreed at a meeting of the Joint Meteorological Committee in November 1944.

Plans : During D.M.O.'s visit, an organisation which was drawn up for the meteorological service in S.E.A.C. represented a substantial expansion upon the earlier organisation. Arrangements were to be made to supply meteorological advice to Supreme H.Q. and to establish a Joint Meteorological Centre at Colombo staffed equally by personnel of the Meteorological Office and of the Naval Meteorological Service. The organisation involved a total of 162 R.A.F. officers and 408 airmen plus 35 I.A.F. officers and 250 airmen.[1] The main administrative centre was to be at H.Q. A.C.S.E.A. (Kandy) and an administrative sub-centre at H.Q. Base Air Forces South-East Asia (B.A.F.S.E.A.) (Delhi). The Joint Meteorological Centre, Colombo, was to be the main forecasting centre for the whole Command, with two area sub-centres at Calcutta (No. 231 Group) and Karachi ; the former would issue information for N.E. India, Burma and the northern part of the Bay of Bengal and the latter would cover N.W. India, the Gulf of Oman and the northern part of the Arabian Sea. Provision was also made for forecasting centres at No. 221 (Bomber) Group, No. 224 (Bomber) Group, Nos. 225 and 222 (Coastal) Groups and No. 223 (Training) Group. The technical difficulties of forecasting in India, the relatively open network of reporting stations and the inability in most cases to obtain technical advice owing to poor communications would make it essential to employ a high proportion of independent forecasters at Wing H.Q. and certain other stations. Provision was also made for reporting units at certain stations and for two Mobile Forecast Centres and four Mobile Meteorological Units chiefly with the Army.

Joint Meteorological Centre, Colombo : Directives for a joint R.A.F.–R.N. Meteorological Centre were given in Air Ministry and Admiralty signals on 30 September 1944. The proposed centre included administrative, forecast and planning sections and a special section known as the ' swell ' section under the control of Chief Meteorological Officer with the Fleet Meteorological Officer as deputy. The proposal was discussed during D.M.O.'s visit and it was decided that it would be best to have the forecast, planning and ' swell ' section in Colombo near Naval Staff and Operational Staff of H.Q. No. 222 Group, and the administrative section with Chief Meteorological Officer at H.Q. A.C.S.E.A. in Kandy. In order to keep both the Supreme Commander and the Air Commander informed of the current weather situation, it was proposed to issue a daily appreciation in relation to current operations. Details were discussed by all concerned in Colombo on 27 October 1944, and in spite of the numerous difficulties to be overcome regarding accommodation, staff and installation of communications, the centre opened on the target date, 1 January 1945. The forecast and ' swell ' sections remained at Colombo until the end of the war, but by March 1945, it had become evident that the planning section would be much better located alongside the Supreme Commander's planners at Kandy. The move was accordingly made and proved a wise one not only from the planning aspect, but it gave the Chief Meteorological Officer a contact in H.Q. S.A.C.S.E.A. and thereby facilitated the meteorological briefing of S.A.C.S.E.A. staff.

[1] *See* Appendix 14.

Besides supplying S.A.C.S.E.A. and A.C.S.E.A. with forecasts for operations in Burma, and the Royal Navy for operations in the whole of the Indian Ocean, the forecasting section supplied information to H.Q. No. 222 Group and associated stations for flights over the Indian Ocean, to Royal Air Force and Qantas airways for flights to Australia, and to Transport Command aircraft flying to India and Burma. Cyclone warnings were also issued to all concerned as occasion demanded. The meteorological staff were drawn equally from Royal Navy and Royal Air Force personnel but signals staff were entirely provided by the Royal Air Force.

An Upper Air Section was formed in May 1945 and upper air contour charts were drawn daily from June 1945. The charts facilitated the forecasting of upper winds, especially on the Ceylon—Australia route, and were of great value in the general analysis and in particular in forecasting outbreaks of bad weather such as often occur in the tropics with little or no indication on the surface charts. Owing to the cessation of hostilities and consequent decrease in the amount of upper air data previously available the research work which was initiated with these charts was not completed.

The 'swell' section consisting of Royal Navy and U.S.A.A.F. personnel, besides supplying forecasts of sea conditions for landing operations in Burma, were engaged in research on the forecasting of swell in the tropics. In connection with this, surf reporting stations were set up at Colombo, Addu Atoll, Cocos, Koggala and Hambantota as well as at a number of stations in India. Automatic wave recorders were installed at Colombo and Addu Atoll. Extended observations lasting for an hour or more were often made at Colombo to investigate the variation in wave height and period. To assist the planners a series of monthly charts were prepared for the Bay of Bengal giving estimated percentage frequencies of sea conditions suitable for different types of operation involving small vessels. Attempts were also made to obtain reports from aircraft by visual and photographic means and also to develop the radar altimeter to obtain heights of waves and swells, but progress ceased on the cessation of hostilities.

With the advent of a planning section, special inquiries which had previously been dealt with by I.Met.D., C.Met.O. and the various forecasting centres on an *ad hoc* basis were referred to that section. Although the main work of the section was supplying meteorological reports for the Inter-Services Topographical Department in connection with projected operations, a large amount of work was also done for the planning staffs of S.A.C.S.E.A., A.C.S.E.A. and East Indies Fleet and the subsidiary Commands, in connection with which reference was made as far as possible to M.O.9, and to the memoranda which were regularly received from that Branch.

H.Q. B.A.F.S.E.A.: With the move of H.Q. A.C.S.E.A. and Chief Meteorological Officer to Kandy in October 1944 and the formation of H.Q., B.A.F.S.E.A. as a subsidiary command, it became necessary to form a subsidiary meteorological centre at H.Q. B.A.F.S.E.A. at Delhi. In the subsequent division of duties, the Chief Meteorological Officer remained responsible for all policy matters and general technical control of all R.A.F. and I.A.F. meteorological units. In the case of operational meteorological units, *i.e.*, those in Ceylon, Bengal and Burma, this control was exercised direct with the relevant Senior Meteorological Officers or stations but for the static meteorological stations in India, namely those at transport air route stations,

control was exercised through the Senior Meteorological Officer, B.A.F.S.E.A. The latter became responsible for the supply of meteorological equipment, forms and publications at all meteorological units throughout the Command, and collaborated closely with the Meteorological Liaison Officer appointed in April 1945 to Headquarters No. 229 (Transport Command) Group at Delhi and with the Headquarters of the India Meteorological Department. The supply and distribution of meteorological cyphers and the training and remustering of both R.A.F. and R.I.A.F. airmen were also placed under the jurisdiction of the Senior Meteorological Officer, B.A.F.S.E.A.

Expansion of R.A.F. and R.I.A.F. Meteorological Sections 1944–1945

With the renewed flow of reinforcements towards the end of 1944, action was taken to strengthen and open new forecast sections in the forward areas. Main forecasting centres were formed in December at H.Q. No. 221 Group, Imphal and H.Q. No 224 Group, Chittagong and the existing I.A.F. meteorological sections of these Headquarters were moved to the local airfields. Further forecast centres were formed in January 1945 at operational bases in Ceylon and at Flying Boat bases in India. The next step was to take over the I.Met.D. stations on the transport routes, one of the first being that at Delhi (Palam) to which incoming forecasters were initially posted to receive instruction in forecasting in the tropics and on the meteorological organisation in A.C.S.E.A. R.A.F. Meteorological offices were opened at Mauripur, Jodhpur, Allahabad and Calcutta on the east–west route across India by 1 April 1945, and a number of the I.M.D. stations on the north–south routes were taken over by 1 May 1945. Unfortunately, owing to the prolongation of the war in Europe and the prior claim of that theatre to meteorological staff, the flow of forecasting officers to A.C.S.E.A. ceased again early in 1945 so that the plans set out above were not fully implemented before the end of hostilities and many of the forecast centres were under-staffed. By the end of hostilities the total strength of officers had risen to 102 against an establishment of 162. Fortunately there was no serious lack of airmen meteorological assistants, the total in August being 377 against an establishment of 408. In October 1944, a R.A.F. Meteorological Training School for airmen assistants was set up at Calcutta; an N.C.O. was allocated as instructor and a two months' course based on the Meteorological Office Training School syllabus was arranged. A steady flow of trainees for remustering to meteorologist passed through the school during the ensuing ten months.

The R.I.A.F. Meteorological Section also continued to expand and by the end of the war had reached a total complement of 29 officers and 143 other ranks. R.I.A.F. stations were opened at Kohat and Bihta but the airmen were employed mainly in mobile forecast or pilot balloon units and the officers to strengthen some of the R.A.F. meteorological units where they took duties on the forecast roster alongside their R.A.F. colleagues.

Strategic Air Force: The work of the meteorological section of Headquarters No. 231 Group continued to increase throughout 1944 and 1945 and additional subsidiary forecasting centres were opened at the associated Bomber stations. After H.Q. 3rd T.A.F. was absorbed in Eastern Air Command, the meteorological section of H.Q. No. 231 Group became the R.A.F. centre for M.E., India and Burma. When the Group moved to Cocos in August 1945, this latter function was taken over by the forecasting centre at Calcutta (Dum Dum).

Tactical Air Force : When H.Q. 3rd T.A.F. was absorbed into Eastern Air Command, towards the end of 1944, the meteorological section was moved to Comilla airfield for use on the transport routes. The work of the meteorological sections of the two tactical R.A.F. Groups, Nos. 221 and 224, is set out in the next paragraph.

The Burma Campaign : The meteorological organisation in E. Bengal and Assam, before the advance into Burma, consisted of No. 721 Forecast Centre at H.Q. No. 221 Group, a forecast centre at Imphal airfield, four subsidiary forecast centres attached to Wings and three mobile units. After withstanding with H.Q. No. 221 Group the siege of Imphal in 1944 No. 721 Forecast Centre moved with the Group H.Q. from north to south through Central Burma to Rangoon during the early months of 1945. The centre was operationally self-contained and at each location a temporary forecast centre was set up in a tent and the supply of information maintained. Each of the forecast centres attached to the Wings of No. 221 Group moved in a similar manner with the Wing H.Q. and owing to communication difficulties were obliged to act as independent forecast units. It had been visualised in planning for the Burma campaign that it would not be possible under mobile warfare conditions to run three forecast centres dependent for advice and guidance on a parent centre at Group H.Q. and this was amply demonstrated. Unfortunately the plan for meteorological W/T point-to-point channels did not begin to operate in the Burma area until May 1945, by which time the main campaign had reached a successful conclusion ; the earlier provision of these channels would undoubtedly have increased the efficiency of the forecasting service during this campaign.

On the Arakan front, in addition to the forecasting units associated with No. 224 Group, special mobile forecasting units were provided for the sea-borne expeditions that recaptured Akyab, Ramree Island and Rangoon and these subsequently provided very useful reporting and forecast centres for the transport and supply routes.

During this campaign, most of the supplies for the Army were airborne and a large number of forecasts were supplied in connection with supply dropping and the building up of supply dumps, during mopping-up operations in 1945 after the fall of Rangoon. By this time the south-west monsoon had broken and aircraft operating from Chittagong, Akyab and Ramree had to fly over the Arakan mountains into central Burma. The supply of forecasts for these flights was a severe test for the forecasters concerned, most of whom were new to tropical forecasting. Considerable assistance was however received from the 'Watchbird' Meteorological Flight of No. 435 Squadron board at Ramree. This flight kept a continuous watch on the weather over the south-west part of Burma throughout daylight hours and information concerning areas of least cloud and levels free from cloud were sent back to base by R/T at very frequent intervals. The information was passed to Squadrons at Ramree and Akyab and proved very valuable in enabling less experienced crews to get through thus reducing the number of abortive sorties.

Air routes from Calcutta to Rangoon, both via the coast route and central Burma, soon began to function and forecast centres had to be provided at the staging posts. Fortunately personnel were available to meet this commitment. The Burmese meteorological service and all internal communications had

become completely disrupted during the Japanese occupation but the forecast centres and the mobile units attached to the Army provided a skeleton synoptic network.

H.Q. No. 222 Group (Ceylon) : In December 1943, squadrons operating in connection with the security of sea communications in the Indian Ocean area, including the Gulf of Aden, Persian Gulf, Gulf of Oman and Bay of Bengal, were placed under the strategic control of the Air C.-in-C. S.E. Asia, exercised through No. 222 Group. In consequence, there was a considerable increase in the area for which S.Met.O. No. 222 Group was called upon to supply meteorological information and it involved the reception of additional synoptic data and the use of a more extensive working chart. Additional meteorological stations had been opened at Ratamalana and Sigiriya in 1943, and early in 1945 further forecast units were sent to the island bases at Addu Atoll and Cocos Islands. The latter station was particularly important as it was the only one sending weather reports on the 3,000 mile flight between Ceylon and Australia. The forecast unit at Cocos relieved the Australian meteorological unit which had been supplying weather reports and upper winds since the end of 1943. By the middle of 1945, aircraft were landing at Cocos and could therefore be rebriefed on weather conditions for the remaining half of the route. Forecasting for Western Australia was difficult, however, owing to the fact that, in the latitude of Perth, pressure systems normally move from west to east and there were no observations over the sea to the west. In this connection it was considered that weather reports from St. Paul's Island, an uninhabited old French whaling station at approximately 37° S. 77° E. about midway between South Africa and Australia, might help, and a survey party went to the island in June 1945. The report of the expedition was favourable and all arrangements were being made to open the reporting station when hostilities ceased and the project was dropped. Full details of the survey were subsequently circulated to countries who were likely to be interested in St. Paul's Island as a post-war meteorological reporting station.[1]

Although the revised organisation made the Joint Meteorological Centre responsible for the supply of information to H.Q. No. 222 Group and associated stations, the Group H.Q. pressed strongly during D.M.O.'s visit for retention of a Senior Meteorological Officer at their H.Q. both for advisory duties and for the administration of the meteorological units at the widely flung stations of the Group, some of which were 1,500 miles away. This officer was accordingly retained and was located in the Joint Meteorological Centre, Colombo, close to H.Q. No. 222 Group.

Other Operational Requirements : In addition to those mentioned, forecast centres for Singapore, Kuala Lumpur and Penang were held in readiness in India for the advance on Malaya, when hostilities ceased.

Meteorological information required in connection with the training of airborne troops had for some time been supplied by the I.Met.D. but in May 1945 a R.I.A.F. forecast centre was formed for the purpose.

Meteorological Organisation on Air Routes : In addition to his duties as meteorological Adviser to the A.O.C., the Senior Meteorological Officer appointed to H.Q. No. 229 Group in April 1945, kept the Chief Meteorological Officer

[1] A.M. Files S.100160, S.94334.

informed of the meteorological requirements for transport operations. His reports enabled the Chief Meteorological Officer and B.A.F.S.E.A. to remedy defects in the meteorological organisation. The appointment of this officer proved of great value in a country the size of India, where so many of the problems could be resolved on the spot and thus avoid the long delays inherent in normal channels of communications. The main air routes for which meteorological information was required were (i) Middle East—Karachi—Calcutta (later extending to Rangoon and Singapore), (ii) Karachi—Ceylon—W. Australia, (iii) Delhi—Bombay—Bangalore—Ceylon, (iv) Delhi—Madras—Ceylon, (v) Delhi—Peshawar, (vi) Ceylon—Calcutta, (vii) Ceylon—Singapore. To provide an efficient meteorological service on these routes it was necessary to exchange weather reports and forecasts between terminals and also to provide a ground to air broadcast of weather reports for landing. In addition, forecast centres were opened at Poona, Arkonam, Drigh Road and Chaklala to meet the special needs of air trooping.

The problem of the interchange of synoptic information was largely solved when the All-India meteorological broadcasts from Nagpur were started but even then, owing to the distances involved, data had to be passed by point-to-point from Karachi to the Middle East and between Ceylon and Australia.

Owing to lack of the necessary signals facilities, the only system of interchange of up-to-date weather reports was by the U.S.A.A.F. organisation, until a scheme for meteorological communications was introduced. Arrangements were made, however, in August 1944 for deterioration and improvement reports to be interchanged between neighbouring Staging Posts using operational W/T channels.

Arrangements for the exchange of route and landing forecasts between Ceylon and Australia have already been mentioned. A similar exchange was arranged between Karachi and Aden and Habbaniya using the M.O.O.F. code. This was also tried out between Karachi and Ceylon but owing to the serious delays in communications, aircraft had invariably departed before the information had been received from the arrival terminal. The I.Met.D. were somewhat more successful on their civil routes, partly because they used land-line telegrams and chiefly because the distances involved were shorter; but here again, messages were frequently received too late and the information supplied had to be based on a synoptic chart several hours old by the time the message reached the recipient.

Owing to tardiness in fulfilling a plan for meteorological communications and the lack of up-to-date information on the Air Routes, No. 229 Group early in 1945 set up a system of station broadcasts on M/F beacons of hourly weather reports in U.C.O. code whereby each station along a particular route broadcast in rotation its actual weather at the time of broadcast. Although the scheme was designed primarily for aircraft in flight, under favourable conditions a large number of these station reports could be received at any one station which thus had a more up-to-date picture of the weather along the different air routes.[1]

Individual briefing of aircrew was normally done by reference to the current synoptic chart, but for mass briefings at busy stations like Karachi a display was arranged on a blackboard showing the forecast synoptic chart for the

[1] A.M. File S.82508/11.

estimated time of departure, a pictorial diagram showing the forecast weather and a vertical cross section of anticipated cloud conditions. Information supplied to aircrews varied with the length of flight. For long flights a written route forecast, vertical cross section and terminal forecast were supplied together with a form for recording weather observations in flight; for very long flights aircrews were provided with a route and landing forecast only. At the busier stations the current forecast and latest weather reports for each air route radiating from the station were displayed in the Meteorological Office. Some of the Briefing Rooms also included a meteorological display board presenting pictorially general climatic features of the region with particular reference to the current season.

Role of the I.Met.D. in 1944–1945

During this period, the I.Met.D. remained responsible for the basic network of observing stations, the regional W/T broadcast scheme in India and for providing forecast centres along the civil air routes. It also continued to provide information to the R.A.F. at those stations on the R.A.F. transport routes, such as Bombay, Nagpur, etc., at which it was agreed that R.A.F. meteorological staff need not be provided. The original reporting network had a number of important gaps especially along the air routes, and the expansion programme had provided for these to be filled. Accordingly, when the change of policy necessitated R.A.F. meteorological staff taking over some of the forecast centres on the air routes, the displaced I.Met.D. staff were used partly to augment the I.Met.D. forecast centres at civil aviation stations and partly to staff new reporting stations. This was the chief feature of the I.Met.D. expansion during 1945.

Communications

Arising from the C.-in-C.'s proposals to Air Ministry in July 1944, the Allied Meteorological Committee called a special conference in August 1944 to consider ways and means of improving and integrating telecommunication arrangements for the collection, exchange and broadcast of data in S.E. Asia and neighbouring areas. The meeting, attended by representatives of A.M.C.O.S.E.A. and also signals officers from A.C.S.E.A. No. 229 Group, U.S.A.A.F. R.N. and Director of Telegrams (Govt. of India), considered the three main problems, namely, the collection of synoptic data, their dissemination to all forecast centres, and the interchange of hourly weather and deterioration and improvement reports between stations along air routes.[1] The problem of the collection and dissemination of synoptic data had been partly solved by developing a system of regional W/T broadcasts. Although this scheme ensured that synoptic data were received at forecast centres it did not ensure rapid dissemination. The I.Met.D. had accordingly prepared a meteorological teleprinter scheme for the rapid interchange of hourly weather reports and synoptic data. The conference recommended its adoption as a long term policy and, it was in the initial stage of implementation when hostilities ceased.[2] As a short term policy for the interchange of hourly weather reports, it was recommended that reports from stations on air routes in the north of India should be included in the U.S.A.A.F. hourly broadcasts from Agra or Calcutta and

[1] A.M. File S.82508/1.

[2] A.M. File A.813728.

that hourly weather reports from the southern half of India should be broadcast from the Madras regional station. Reports from stations in Ceylon would be available on the naval transmitter at Colombo. The Madras hourly broadcast started in August 1945 and reports were collected from stations over two W/T channels, one connecting Madras with Yellahanka, Madura and Trichinopoly and the other with Colombo, Hakimpet and Vizagapatam. A W/T channel was also provided linking Colombo with other stations in Ceylon, viz., Minnerige, Koggala and Kanlesanturai.

It was not found possible to integrate requirements in N.E. India and Burma with existing or proposed U.S.A.A.F. broadcasts owing to the necessity for any scheme prepared for the forward areas to be flexible. A scheme was therefore prepared which divided the forecast centres to be inter-connected into four groups. All stations within a group would report to their respective H.Q. within 15–20 minutes. Group centres would then interchange collective reports either by point-to-point or, alternatively, all groups would send their collectives to a central collecting station for broadcast. The method of distribution was to be flexible so that it would not be unduly disturbed as reporting units moved forward ; it would also be such that additional reporting stations could be added to the network. It was not, however, until February 1945 that this scheme began to be implemented in the forward area. There were numerous troubles in the early stages and it was not until June that the scheme was really working satisfactorily throughout the area of E. Bengal and Burma. East group was allotted a frequency on which it collected observations from its own stations, and then broadcast its collective in turn on the inter-group frequency but using point-to-point procedure. Finally each Group, on its own frequency, broadcast to its own stations the reports it had collected from other Groups.

The conference of the Allied Meteorological Committee also confirmed the previous recommendations, included in Signals plans, for five meteorological broadcast centres for reoccupied territories and ten low power mobile W/T vans for sending in hourly weather reports from strategic points for broadcast. Other recommendations included the provision of an additional transmitter at Karachi directed to Habbaniya for the supply of synoptic data and hourly weather reports for the Karachi Habbaniya route, an increase in the power at Nagpur Central W/T station and an amendment of the Nagpur retransmission so that little duplication occurred with the U.S.A.A.F. Calcutta, Agra or Kunming transmissions and so that a station with two receivers, one tuned to Nagpur and the other to one of the U.S.A.A.F. broadcast stations, could receive all the data from India and China.

Organisation for the Army

There was hardly any meteorological organisation for Army units until 1942 when arrangements were made to supply information, chiefly Meteor reports, to certain static Army stations by both I.Met.D. and the R.A.F. Meteorological Service in Ceylon. The Army, however, required information in the forward areas and by 1943 investigations had shown that a central forecast office could not forecast winds accurately enough up to 10,000 feet on the hilly country of Assam and Burma. It was necessary therefore to form mobile meteorological units for the Army in the field and provision for ten

such units, seven R.A.F., three I.A.F., had been included in the July 1942 programme of expansion. Owing to lack of meteorological personnel and the urgent need for these units, the Artillery during 1943 arranged for the training (by I.M.D.) and formation of its own four meteorological sections, until such time as they could be staffed by meteorological personnel. The position was reviewed with G.H.Q. India in February 1944 and further demands were made for a total of three mobile forecast units and 13 mobile pilot balloon units ; the former were to be attached to Corps H.Q. and the latter mostly to Divisional H.Q. ; forecasts for Army H.Q. would be supplied by the forecast section of 3rd T.A.F. As a number of both R.A.F. and I.A.F. airmen were then under training it was agreed to form the above units at the rate of one per month. The first was formed in October 1943, the second in April 1944 and thereafter further units formed at approximately two-monthly intervals. By the end of the war nine units were in the field and four more were awaiting deployment.[1]

Fortunately both Nos. 2 and 1 Survey Regts., which arrived in the theatre in July 1943 and September 1944 respectively, brought their own fully equipped meteorological units with them. Both units operated as two sections for the rest of the war and took part in the Burma campaign. The normal Meteor computations and sound ranging work was carried out. These sections came under the general technical control of C.Met.O. on entry into A.C.S.E.A.

All mobile units were provided with a vehicle and the mobile forecast centres had, in addition, a signals vehicle. The earlier vehicles provided were large 30 cwt. office tender prime movers and although they were often the most comfortable working equipment of the army division, they were difficult to manipulate in the tracks of Burma and were frequently bogged. They were subsequently replaced by smaller 15 cwt. vehicles incorporating front wheel drive, an essential element during the monsoon in Burma. These vehicles were specially designed and included a small table, seats, racks and cupboards for instruments, stores and hydrogen generators.

A considerable amount of work was involved in forming each mobile unit and in arranging for its transport to the operational base. This work had largely been done by S.Met.O. H.Q. No. 231 Group Calcutta, but when officer reinforcements arrived at the end of 1944, an officer was attached to the S.Met.O.'s staff as Army Liaison Officer and took over these functions. This officer worked in close liaison with H.Q. Allied Force S.E. Asia, inspected the units at their operational bases, and was instrumental in improving the general welfare and efficiency of the units.

Weather forecasts for the operational area were regularly supplied to H.Q. Fourteenth Army and to Corps H.Q. by the nearest appropriate forecast centre.

Upper Air Data

With most of India and S.E. Asia lying in the tropical zone, surface pressure charts often conveyed little to the forecaster and an adequate supply of upper air data was essential. This had long been recognised by the I.Met.D. and

[1] A.M. File S.82012.

even at the outbreak of war there was a good network of pilot balloon stations. By mid-1943 the number had increased to 53 and others were added up to the end of the war. In the forward areas the network was maintained by the R.A.F., I.A.F. and U.S.A.A.F. meteorological units. From the middle of 1944, by co-operation with certain units of the Royal Artillery, upper winds were also obtained by radar method and these proved especially useful during cloudy conditions.

Until the middle of 1943, upper air temperatures were obtained on an *ad hoc* basis from aircraft ascents but were very infrequent. A scheme for four regular Meteorological Flights (Vertical Ascents) was approved by Air Headquarters, India, in May 1943 and the first flight started at Calcutta in July 1943. Considerable trouble was experienced, however, in finding suitable aircraft and it was not until August 1944 that the four flights became fully operational at Calcutta, Nagpur, Colombo and Madras using Hurricane aircraft. In the meantime, the U.S.A.A.F. had by mid-1943 installed three radio-sonde stations in India and two in China, and experiments by the I.Met.D. with radio-sondes were reaching the final stages. With the prospect of many more radio-sonde stations becoming available, a network of some 56 locations spread throughout the whole of East and Southern Asia, was agreed by the A.M.C.O.S.E.A. in July 1944. By the end of hostilities about one-half of this network had been completed, mainly by the U.S.A.A.F. weather organisation.[1]

Meteorological Flights

The reporting network had been steadily increasing throughout the war over the land area, but there had been no comparable increase in reports from the sea area. In fact the position was worse than in peace-time owing to the complete absence of reports from ships. This was a considerable handicap to forecasters in supplying information, both for operations and the air routes, especially in respect of the development and movement of tropical storms and changes during the S.W. Monsoon. The long flights involved and the lack of suitable aircraft, made it impossible at first to arrange for regular Meteorological Reconnaissance Flights, but post-flight reports were received at irregular intervals from the flying boats of No. 222 Group, the heavy bombers of No. 231 Group and the Qantas aircraft operating on the Ceylon—Australia route. In April 1944, however, A.C.S.E.A. arranged for meteorological flights to be made by Catalinas operating from Red Hills (Madras) over the Bay of Bengal. Although the arrangement was on an *ad hoc* basis and as part of a general training programme, flights were made on most days for a year and provided most valuable information not only for day to day forecasting but for general climatological purposes. By mid-1944 arrangements had also been made at Headquarters No. 231 Group for meteorological flights to be made on a request basis from Calcutta on a S.E. track over the Bay of Bengal. These flights were designed to assist in the forecasting for specific operations but were largely superseded by the daily sorties of the weather reconnaissance aircraft of No. 10 U.S.A.A.F. Weather Squadron (which became established on a routine basis by the end of 1944) on a track over the Bay of Bengal between Calcutta and Ceylon.

[1] A.M. File S.100160.

The above flights, however, were by no means adequate[1] and on 10 November 1944 Air Ministry were asked to approve the provision of enough aircraft and personnel for :—

(*a*) One daily sortie eastwards from Madras, radius 900 miles (N.E. in August and S.E. in December).

(*b*) One daily sortie from Ceylon south-eastwards—minimum radius 900 miles.

(*c*) One daily sortie between Diego Garcia and Seychelles from May to October.

(*d*) One daily sortie westwards from Kelai from November to April, radius 900 miles (N.W. in November, S.W. in April).

(*e*) One daily sortie due eastwards from Addu Atoll (radius 700 miles).

It was also proposed to provide Meteorological Air Observers for these flights. The E.R.P. Committee in London in February 1945 gave provisional approval but the supply of the necessary aircraft and personnel was postponed until after the cessation of the European war. The implementation of the programme was still in abeyance at the end of the war.[2]

Relations with Allied Meteorological Services

China : Considerable difficulty was experienced in obtaining synoptic observations from China. At first liaison was maintained through the Air Attaché, Chungking, but owing to frequent changes of code, often without notification, and lack of complete knowledge of the precise location of some of the reporting stations, the observations broadcast by the Chinese from Chungking, Changan, Yungan and Kweilin were often of doubtful value. Liaison was further made difficult by the fact that there were two distinct Civil and Military Meteorological Services in China which appeared to be completely independent. It was not until the U.S.A.A.F. Weather Service became established in China that more reliable observations were obtained. Reports were obtained from the U.S.A.A.F. stations and a collective of Chinese observations was sent to the U.S.A.A.F. Weather Control in Delhi (later Calcutta) whence it was passed to R.A.F. meteorological units in the Bengal Area.[3]

A special broadcast of synoptic data for China had been arranged by the I.Met.D. from Poona in May 1942 but this ceased in January 1944 on the request of the Chinese who were no longer able to receive the data owing to lack of material and personnel.

U.S.A.A.F. Weather Service : During the autumn of 1942 a body of American meteorologists was being collected at various points in India viz. Rear echelon, H.Q. Delhi, Calcutta area, Agra and Karachi. The initial development of the U.S.A.A.F. weather service was mainly to provide observers at regular intervals along the main East–West route across India and over the 'Hump' into China and forecasting offices at main bases. Until the formation of the Allied Meteorological Committee S.E. Asia in March 1944, co-operation was chiefly effected through the Joint Meteorological Committee to which the American

[1] A.M. File S.104171.
[2] A.M. File S.96516/1.
[3] A.H.Q. India File 117/18/Air.

meteorologists were invited when their advice and co-operation were required, but by mid-1943 an interchange of basic weather data had been arranged between the U.S.A.A.F. and I.Met.D. at those stations where both services were represented.

By January 1944, the U.S.A.A.F. had established regional W/T broadcast centres at Kunming, Chabua, Calcutta and Agra[1]. Information consisting of synoptic reports, upper winds, radio-sonde reports and hourly observations was sent out on a power of 3 kW by each station in rotation every hour throughout the 24 hours and proved extremely useful to forecasting centres in the forward areas. A collective broadcast of radio-sonde and aircraft reports was also made from Calcutta once daily. Arrangements were made later in 1944 to include certain special hourly reports in the Calcutta and Agra broadcasts from I.Met.D. and R.A.F. meteorological offices on the air routes that could not be readily fitted into the R.A.F. plan of hourly broadcasts. This was agreed by the Allied Meteorological Committee which made further recommendations with the object of ensuring that a station with two W/T receivers, one tuned to Nagpur and the other to one of the U.S.A.A.F. broadcast stations could receive all the data from India and China.

A large measure of agreement was reached on the use of codes. In particular the code to be used for passing landing weather reports to aircraft had presented difficulties, the I.Met.D. and R.A.F. using the international abbreviated weather report code and the U.S.A.A.F. using ALACO. This question was discussed in Delhi in July 1944 and agreement was reached on the use of UCO which was brought into effect on 1 December 1944.

Co-operation with the U.S.A.A.F. was especially valuable in regard to weather reports from China. Not only were these obtained from the U.S.A.A.F. stations in China but a collective of Chinese observations was made available through the U.S.A.A.F. Weather Control in Delhi (later Calcutta).

During the period 1943–1945 the U.S.A.A.F. installed some 25–30 radio-sonde stations throughout China and S.E. Asia and the observations were made available to all meteorological services. The Weather Region was also provided with a flight of Mitchell aircraft which operated from Calcutta for meteorological reconnaissance purposes, and these provided valuable information over the Bay of Bengal.

It was in the Calcutta area that the closest co-operation was maintained with the U.S.A.A.F. Weather Service. The H.Q. of the 10th Weather Region was at Barrackpur and supplied the information required by the U.S.A.A.F. side of H.Q. Eastern Air Command. For a time, the H.Q. of the Strategic Air Force with its subsidiary H.Q.s, viz., No. 231 Group and U.S. Strategic Air Force, were all located in the same building at Fort Belvedere together with their associated forecasting sections. A U.S.A.A.F. Weather Officer was nominally appointed as Chief of the Weather Section, H.Q. Strategic Air Force, but in practice the R.A.F. meteorological section plotted the charts and issued forecasts to their own units whilst the U.S.A.A.F. Weather Section used the charts for issuing forecasts to their own units. The Air Staff were advised by U.S.A.A.F. and R.A.F. meteorological officers on alternate days, an agreed picture being presented. The scheme appeared to work satisfactorily and

[1] A.M. File S.82508/I.

on the R.A.F. side the integration with the U.S.A.A.F. was especially beneficial as regards communications. A teleprinter link with H.Q. 10th Weather Region was installed and data, particularly from China, were obtained that would not otherwise have been available.

Manila Conference : The prospect of the early end of the war in Europe and a consequent intensification of the war against Japan leading to the occupation of enemy-held territory and the eventual closer proximity of allied meteorological staffs in the Pacific, East and South-East Asia, made a meteorological conference on the lines of the Washington conference of October 1943 very desirable in March 1945. The conference was held at Manila (Philippines) in June 1945, and was attended by Chief Meteorological Officer A.C.S.E.A. and the Fleet Meteorological Officer (East Indies Fleet). The U.S. Navy and U.S.A.A.F. in the Pacific, China, India and Burma theatres, and Australia and New Zealand were also represented and observers came from S.A.C.S.E.A. British Pacific Fleet, Royal Australian Navy and C.M.C. Washington. Agreement was reached on the various meteorological codes and cyphers to be used throughout the area covered by the war against Japan and the necessary broadcasts of synoptic reports and analyses. It was confidently expected that this agreement would hold right up to the end of the war, but a number of the scheduled changes had not been effected by the time the war ended in August 1945.[1]

The Manila conference was specially beneficial in the contacts that were made between the meteorological staffs of the various Commands. This was particularly true in the case of Australia. On his way to and from Manila the Chief Meteorological officer, A.C.S.E.A. passed through Australia and took the opportunity to discuss deficiencies in the exchange of data between A.C.S.E.A. and Australia particularly as it affected the Ceylon—Australia air route, and to make preliminary plans regarding the transfer of meteorological sections to the Netherlands East Indies as they were reoccupied.

I.Met.D. : Close collaboration and willing help were received at all times from the I.Met.D. Not only were the day to day synoptic observations and climatological data placed at the full disposal of the Allied Meteorological Service but much valuable help was given to the R.A.F. by the I.Met.D. in respect of equipment. Early in 1943, arrangements were made for all the R.A.F. meteorological equipment sent to India to be stored at the Headquarters of the I.Met.D. in Delhi and issued from there on demand. The R.A.F. meteorological service was thereby relieved of a large amount of work in storing and packing of equipment. Further, it was possible for instruments to be calibrated and repaired in the I.Met.D. workshops. Owing to the great distances of some of the R.A.F. units from Delhi, subsidiary centres for R.A.F. meteorological stores were subsequently opened at Calcutta, Colombo and Rangoon.

Owing to the uncertainty of the supply of forms from England, arrangements were made to print most of the forms, including synoptic charts, in India ; these were distributed through R.A.F. channels. Considerable assistance was also given by the Survey Department 11th Army Group in the preparation and printing of synoptic charts, but for a long period prior to this I.Met.D. charts were used.

[1] A.M. File S.96516/I.

The proximity of the I.Met.D. liaison officer to the Chief Meteorological Officer at Air Headquarters proved extremely useful as it enabled day to day discussions to take place and decisions to be made on the various problems that arose especially during the build-up period of 1943 and 1944.

Immediate Post-War Reorganisation

The re-occupation of enemy-held territory considerably increased the area covered by air routes, *i.e.*, from the Persian Gulf to Japan and from N.W. India to Australia. Forecasting centres and mobile reporting units were already standing by as part of the expeditionary force for Malaya but it was necessary to deploy those meteorological units which were no longer required for operational purposes. The national meteorological services and communications had been considerably disrupted by the Japanese occupation and pending their resuscitation the deployed meteorological units had to be largely independent and self supporting. Agreement was reached with the Australian Weather Bureau regarding the areas to be covered by the respective meteorological services.

Arrangements were made to move the Chief Meteorological Officer with Headquarters A.C.S.E.A. to Singapore, to disband the Joint Meteorological Centre, Colombo, and to move forecasting centres to Malaya, Java, Sumatra, Borneo, Hong Kong, Indo China (Bangkok), Siam (Saigon) and Japan. The mobile pilot balloon units which had been so long in forming proved extremely useful at this stage ; they were withdrawn from service with the Army, provided with signals facilities and used as reporting units in such locations as Tavoy and Mergui on the main air route Rangoon—Singapore.[1]

In India, with the disbandment of Headquarters No. 231 Group the main forecasting centre in Calcutta was transferred to the airfield at Dum Dum and no further R.A.F. meteorological stations were opened. The complete plan for meteorological reorganisation was, therefore, never fully implemented.

With regard to communications, arrangements were made for meteorological point-to-point channels linking centres in Malaya and N. Sumatra with the controlling centre in Singapore and centres in Java, S. Sumatra and Borneo with a controlling centre at Batavia. A direct line between Batavia and Singapore was also provided. The development of meteorological point-to-point channels in Burma and Bengal has already been noted ; the provision of two regional broadcast centres at Rangoon and Singapore made possible a complete interchange of weather reports in S.E. Asia.

Technical Problems

The same meteorological problems arise in S.E. Asia as in other sub-tropical areas, *e.g.*, in respect of tropical storms and convection phenomena generally, the inter-tropical front or convergence zone, the effect of orography, etc. In particular, the formation and development of monsoon depressions required further study ; these depressions had already been carefully investigated by I.M.D. officers who had produced valuable papers on the subject, but although useful empirical aids to forecasting had been formulated, more research was still needed in the light of upper air data.

[1] *See* Appendix 15 for the meteorological organisation at the end of the war.

Some of the problems were studied by forecasters in the operational area as well as at Meteorological Office H.Q., and several papers were produced, *e.g.*, S.D.T.M. 117 'Flying conditions in the South-West Monsoon in India and neighbouring areas', S.D.T.M. 120 'Winter circulation over Burma, Thailand and Indo-China', S.D.T.M. 123 'Notes on forecasting in North-East India and neighbouring areas', and various Aviation Meteorological Reports M.O.M.365/33.

The abnormal range obtained with V.H.F. and radar transmissions under certain meteorological conditions had been studied in the United Kingdom by the Joint Meteorological Radio Propagation (J.M.R.P.) Sub-committee of the Meteorological Research Committee. Very pronounced effects were found in certain regions of the Far East including the Bay of Bengal, and the J.M.R.P. Sub-committee recommended that further investigations be made in the Bay of Bengal and proposed that forecasts be issued within A.C.S.E.A. indicating the propagation conditions expected day by day. The subject was discussed during D.M.O.'s visit to A.C.S.E.A. and it was agreed that the C.Met.O., A.C.S.E.A. should act as co-ordinating officer for this work, to supervise which, a specialist officer from the United Kingdom was attached to the Joint Meteorological Centre, Colombo, at the end of 1944. Early in 1945, notes for the guidance of meteorologists were circulated to the forecast centres where meteorological officers were expected to be called upon to supply forecasts in connection with the investigation. It was arranged for the Madras Meteorological Flight to make a series of special temperature observations at different heights over the sea, coast and land for incorporation in a paper on the structure of the sea-breeze with particular reference to temperature and humidity gradient and associated radio ducts. J.M.R.P. reports Nos. 61 and 74 on the radio-climatology over the Bay of Bengal and coastal areas of Siam, Malaya, Sumatra and Java were distributed, and coverage charts of various radar stations under both normal and anomalous conditions were prepared in conjunction with the Radio Counter-measures Section, S.A.C.S.E.A. The work ceased at the end of the war before the information which had been gained could be applied in day to day forecasting of propagation conditions.

Owing to the sparse reporting network and lack of observations over the sea areas, one of the major difficulties in S.E. Asia was forecasting the development and subsequent movement of thunderstorms. As these storms often covered large areas, extended to great heights and were often very violent, a knowledge of their behaviour was essential to forecasting for operations, particularly at night, and also for the air route organisation as some diversion airfields were several hundreds of miles apart. It was accordingly arranged in May 1944 that Filter rooms should report to the local forecast centre all reports of observations of lightning flashes and towering cloud masses seen on the radar screen, together with subsequent movements. These reports were distributed to neighbouring forecast centres and proved of such value that an extended distribution was made to forecast centres from March 1945. At the end of the war, a scheme was being tried out to give complete radar coverage of an area surrounding one of the trunk route airports. A number of aircraft had also been fitted with equipment for detecting cumulo-nimbus cloud, particularly at night, the idea being to discover whether avoiding action could thereby be taken. The investigation was continued after the end of the war.

CHAPTER 25

ICELAND, JAN MAYEN AND FAEROES

Iceland

Reports from Iceland are of fundamental importance to a European forecaster. After the outbreak of war, the Icelandic Meteorological Service continued to broadcast its collective synoptic messages in clear, and many months were spent unsuccessfully negotiating to have the broadcasts suppressed and to obtain the reports for the exclusive use of the Allies.[1] When the occupation of Iceland was being planned, therefore, it was decided to include a meteorological officer in the expedition, with the dual aim of ensuring that the Iceland reports were withheld from the enemy but reached Britain with the minimum of delay and of meeting any meteorological needs of the British Forces in Iceland. The Service requirements were then somewhat nebulous and it was hoped that, if the meteorological officer could enlist the help of the Icelandic Meteorological Service, he would be able to provide the necessary meteorological service until the Service needs were more clearly defined. At that time, the only regular broadcasts of meteorological data from the United Kingdom were the Fleet Synoptic Broadcasts, and the meteorological officer was provided with the appropriate cyphers so that he would have access to the data if the broadcasts could be intercepted. The occupation party (Alabaster Force) consisted of Marines and included four diplomats, headed by the British Minister elect for Iceland, and the meteorological officer. It reached Reykjavik harbour at 0500 hours on 10 May 1940.

The British Meteorological Organisation

As soon as the force was landed, the meteorological officer went to the Icelandic Meteorological Office (Vedurstofan) and contacted the Chief Forecaster, the only meteorologist on duty. As the result of an appeal, the entire staff reported for duty within an hour. The Vedurstofan staff consisted of the Director, the chief forecaster and two other forecasters, two wireless operators-cum-meteorological assistants, and two typists who also assisted in climatological computations. The staff remained almost unchanged during the war, except that an extra wireless operator was engaged for a time and paid from Air Ministry funds, to undertake the reception of additional information required. The general level of efficiency of the personnel was very high, bearing in mind the isolation of Iceland from other meteorological centres. The Icelandic forecasters willingly put their knowledge at the disposal of the British occupation forces.

The Icelandic meteorological organisation at that time consisted of the H.Q. office in Reykjavik, at which full observations and pilot balloon ascents were made, and some 20 outstations. The only full-time staff was that at Reykjavik, but several other stations were manned by part-time personnel such as lighthouse keepers, who made observations at the main synoptic hours. The Icelandic

[1] *See* Appendix 16 for a map showing the principal meteorological stations in Iceland.

collective broadcast consisted of about eight reports from stations well distributed round the island. Most stations were completely equipped with instruments for surface observations, and the general standard of reports was high. Reports were passed mainly by telephone direct to the Vedurstofan, a very reliable channel of communications. A room in the Vedurstofan was taken over and it was arranged to intercept broadcasts from the United Kingdom; these were all decyphered by the meteorological officer himself as no cypher staff were available from the British Forces. Two charts were drawn up daily.

During the summer of 1940 it was decided to base a squadron of Battle aircraft (No. 98 Squadron) in Iceland, and arrangements were made to provide the necessary meteorological organisation. In August 1940, a Type 1 meteorological office was set up at Reykjavik in offices adjoining the H.Q. of the Vedurstofan, and a Type 3 office was set up at the R.A.F. airfield at Kaldadarnes on 2 August 1940. The meteorological staff had been increased by October to five officers and twelve other ranks. It was then decided to withdraw most of the personnel of No. 98 Squadron, leaving the aircraft at Kaldadarnes to be manned again in the spring. In November, a corresponding reduction in meteorological personnel was made, leaving only two officers and three other ranks, and the meteorological office at Kaldadarnes was down-graded to a Type 4. No 98 Squadron, however, carried out much more flying than was expected, and it became necessary to ask for additional meteorological staff. Two officers and three other ranks were posted from the United Kingdom; on their arrival at Kaldadarnes the office was up-graded to Type 3 again.

The intensification of the Battle of the Atlantic and the end of the winter weather in Iceland resulted in a great increase in air operations from Iceland. No. 30 Wing, which was later replaced by Area Combined H.Q., Iceland, and No. 100 Wing (Flying Boats) arrived in April. H.Q. No. 30 Wing was set up in Reykjavik, and the flying boats were stationed at a fjord adjoining Reykjavik airfield. Kaldadarnes was also reinforced in April by the arrival of No. 269 Squadron (Hudsons). A Norwegian float plane squadron arrived in May; detachments of this squadron were stationed in Reykjavik, Akureyri and Budareyri. The airfield at Reykjavik was gradually brought into use and when H.Q. No. 100 Wing left in July, the control of the flying boat squadron was vested in R.A.F. station, Reykjavik (airfield).

The post of the Meteorological Officer-in-Charge in Iceland was up-graded in July 1941 to squadron leader and, in order to meet the much increased needs of the R.A.F., the meteorological staff was increased to five officers and ten other ranks by 8 August 1941. The meteorological office in Reykjavik now functioned as a central forecasting station and that at Kaldadarnes as a distributive station: the former met the needs of Nos. 30 and 100 Wings, R.A.F. Station, Reykjavik, and the float plane detachments at Akureyri and Budareyri; the latter, under guidance from Reykjavik, met the needs of the two squadrons stationed at Kaldadarnes. Shortages of staff made it very difficult to maintain 24-hour forecast services at both Reykjavik and Kaldadarnes.

The Type 1 meteorological office was transferred to R.A.F. Station, Reykjavik, on 9 August 1941, a subsidiary office being set up at the Icelandic meteorological office in Reykjavik town. A reporting station was opened at Akureyri on 4 October 1941; a meteorological officer had been posted there in August 1940 but was withdrawn in October 1940.

Functions of the Meteorological Offices in the Spring of 1942: The Senior Meteorological Officer was at the meteorological office, R.A.F. Station, Reykjavik, from which the administration of the R.A.F. Meteorological Service was conducted. The Office was also the main forecasting office, and a 24-hour forecasting service was maintained with three forecasting officers (excluding the Senior Meteorological Officer) and nine other ranks. The functions of this office were :—

(*a*) To issue written forecasts to all aircrews leaving Reykjavik and to brief them before take-off.

(*b*) To provide meteorological advice and information to the Operations Staff at Reykjavik Station.

(*c*) To give meteorological advice and information by telephone to A.C.H.Q. Reykjavik and to send a representative to the daily conference at A.C.H.Q.

(*d*) To issue by telephone, forecasts for all flights from Akureyri and Budareyri and, during the period 0001–0600 hours, from Kaldadarnes.

(*e*) To issue, on request, advisory forecasts to bases in the United Kingdom for flights from the United Kingdom to Iceland.

(*f*) To issue by telephone to the meteorological offices at Reykjavik town and at Akureyri, data for the computation of artillery Meteor reports.

The observational routine consisted of full hourly meteorological reports.

A forecasting service was maintained at Kaldadarnes from 0600 to 0001 hours daily, but an hourly observational routine was maintained throughout the 24 hours. During the period 0001 to 0600 hours, forecasts were supplied as necessary by telephone by the meteorological office at R.A.F. Station, Reykjavik. Artillery Meteor reports were also prepared at Kaldadarnes for issue to local Army units.

A small meteorological office was maintained at Akureyri, its main functions being to issue forecasts received from Reykjavik to aircrews operating from Akureyri. In addition, artillery Meteor reports for Army units in the vicinity were computed from data supplied by Reykjavik.

A small meteorological office was maintained at the Icelandic Meteorological Office in Reykjavik Town. The functions of this small but important office were :—

(*a*) To obtain from Icelandic Meteorological Office the synoptic weather reports received there by civil telephone and telegraph from all the Icelandic stations, and to pass these reports immediately on receipt to R.A.F. Station, Reykjavik.

(*b*) To prepare the encyphered collective synoptic messages for transmission to the United Kingdom.

(*c*) To assist the staff of the Icelandic Meteorological Office in making synoptic observations and pilot-balloon ascents as the Vedurstofan was unable to man the office throughout the 24 hours.

(*d*) To compute and distribute all artillery Meteor reports needed by Army units except those supplied by Kaldadarnes and Akureyri.

(*e*) To work out sun and moon tables for general distribution.

(*f*) To prepare with the Icelandic Meteorological Office, the monthly bills for the charges for extra reports made at Icelandic reporting stations at the request of the R.A.F. A sum equivalent to the pre-war monthly contribution to Iceland from the International Meteorological Organisation was also paid by the R.A.F.

New Meteorological Office at A.C.H.Q.: The A.O.C., Iceland, stated in August 1942 that the arrangements for supplying meteorological information to A.C.H.Q. were inadequate, and another forecasting office with a 24-hour service was then set up at A.C.H.Q. This office then became the main forecasting office for operational flights. The S.Met.O. moved to A.C.H.Q. and the administration of the R.A.F. meteorological service was transferred from Reykjavik to A.C.H.Q. The functions of the A.C.H.Q. meteorological office were :—

(*a*) To provide meteorological advice and information to R.A.F. and R.N. Operations Staff at A.C.H.Q.

(*b*) To issue, by telephone, forecasts for all operational flights from Reykjavik, Akureyri, Budareyri and, between 0001–0600 hours daily, from Kaldadarnes.

(*c*) To issue, by telephone, to the meteorological offices at Reykjavik Town and Akureyri, data for the computation of Meteor reports.

A 24-hour forecasting service was maintained at R.A.F. Station, Reykjavik, and this office became primarily responsible for forecasting for non-operational flights. It also supplied flight forecasts and briefed aircrews for operational flights from Reykjavik on the basis of information passed from A.C.H.Q. The opening of the meteorological office at A.C.H.Q. also enabled the operational and non-operational forecasting commitments, both of which were then increasing rapidly, to be allocated broadly to separate forecasting offices; experience showed that such an allocation of duties was a wise policy.

Staffing Problems: The shortage of personnel caused many difficulties in 1942 and, in December 1942, the Treasury agreed to an increased establishment. Enough reinforcements were then made available to meet adequately the growing meteorological requirements, and by April 1943, the staffing position was satisfactory. The evacuation of Kaldadarnes in March 1943 made available most of the staff at that station, but one officer had to be retained there as it served as an operational diversion airfield.[1]

By local arrangement with the R.A.F., three aircrafthands G.D. were trained in the spring of 1943 to perform some of the non-technical work of the meteorological airmen who were seriously overworked. In June 1942, Air Ministry authorised the allocation of six Clerks G.D. to the R.A.F. Meteorological Service in Iceland for non-technical duties. These men, five of whom worked at R.A.F. Station, Reykjavik, proved very useful. The sixth Clerk G.D. assisted the Senior Meteorological Officer at A.C.H.Q. The Clerks' duties included telephoning, duplicating of forecasts, coding and decoding, etc.

Closing and Opening of Meteorological Offices in 1943: An ice-block in the river near the airfield at Kaldadarnes caused the airfield to be flooded in March 1943 and the whole station was evacuated. No further operations were possible from Kaldadarnes and the squadron there was transferred to Reykjavik.

[1] A.M. File S.62779/II.

A reporting station was maintained at Kaldadarnes as long as possible but in the autumn of 1943, the meteorological staff and almost all the meteorological equipment were transferred to Reykjavik.

The reporting station at Akureyri was also closed down in November 1943, after which date the staff of the Icelandic Police Station at Akureyri maintained the supply of reports throughout the 24 hours.

The heavily equipped V.L.R. Liberator aircraft which arrived in May 1943 required the longer runways of Meeks Field for take-off, and a subsidiary forecasting office with a full 24-hour watch had to be opened at the R.A.F. Detachment, Camp Geck at Meeks Field. Telephone and teletype connections to the main communications network were hurriedly arranged and were working by the required date. The forecasting office was opened in October 1943 and supplied forecasts and briefed crews for all operational sorties from Camp Geck until the end of the war. Close liaison was maintained with the duty forecaster at A.C.H.Q., who was responsible for advising the duty operations officer regarding meteorological conditions affecting the Liberator flights, and with the U.S.A.A.F. Weather Office, on the other side of the airfield, particularly regarding landing conditions at Meeks Field which often had very different weather conditions from Reykjavik.

Organisation at the End of the War in Europe: The only major development after the opening of the office at Camp Geck was the re-opening of the Coastal Command Operations Room at Reykjavik airfield on 1 February 1945. This involved briefing and de-briefing Coastal Command crews at Reykjavik airfield instead of at Combined H.Q.

The R.A.F. meteorological organisation in Iceland in the spring of 1945 was briefly as follows :—

(*a*) A Type 1 meteorological office at Area Combined Headquarters, about two miles north of Reykjavik airfield, advised the Air Officer Commanding and his staff on all meteorological questions connected with the planning and execution of operations; it also provided meteorological advice required by the Admiral and Naval Staff.

(*b*) Another Type 1 meteorological office at Reykjavik airfield supplied forecasts required by all transit aircraft; prepared, in consultation with A.C.H.Q. meteorological office, the flight forecasts for sorties by aircraft of Coastal Command; and briefed crews of the meteorological reconnaissance aircraft. It was the collecting centre, although not the actual receiving centre, for all the basic data required by the British meteorological service, and decyphered the messages and disseminated the data over the teleprinter network. It also encyphered the forecasts and analyses transmitted by W/T point-to-point channels to the United Kingdom and Canada.

(*c*) A Type 3 meteorological office at Camp Geck supplied meteorological information to Coastal Command operational aircraft with the R.A.F. Detachment operating from Meeks Field.

(*d*) A Type 4 meteorological office in Reykjavik Town collected and distributed reports from Icelandic stations (maintained under the supervision of the Icelandic Meteorological Service) and encyphered the reports for broadcast.

In addition to the R.A.F. meteorological offices, the U.S.A.A.F. had a large weather office at Meeks Field operating throughout the 24 hours.

Communications

Telephone Tie-lines : Adequate telephone facilities were provided between the various units of the British Meteorological Office and with the Icelandic Meteorological Service. A telephone tie-line was installed in August 1941 between the Type 1 office at Reykjavik and the American Naval Meteorological Office on board U.S.S. *Goldborough* (replaced in September 1941 by the U.S.S. *Badger*). Early in 1942, the American Naval Meteorological Office left the depot ship and set up their office on shore near Reykjavik airfield. The Type 1 office at Reykjavik was then connected by telephone to both the U.S.A.A.F. meteorological office and to the U.S. Naval meteorological office.

Considerable use was made of these telephone lines for the exchange of meteorological information and in June 1942 a ten-line telephone switchboard was installed in the meteorological office at Reykjavik. This proved extremely useful. In August 1942, the meteorological office at A.C.H.Q. was also connected by a tie-line with the meteorological switchboard at Reykjavik. Thus, all offices were linked by telephone through this switchboard and telephone conferences were held twice daily at 0200 and 1400 hours G.M.T. between the forecasters at A.C.H.Q. and those in the R.A.F., U.S.A.A.F. and U.S.N. meteorological offices at Reykjavik and Meeks Field.

Teleprinter Network : A meteorological teleprinter circuit was set up on 25 September 1941 between the Type 1 office at Reykjavik airfield and the Type 3 office at Kaldadarnes, and operated until Kaldadarnes was flooded and abandoned. Eventually, the British meteorological offices at Reykjavik airfield, A.C.H.Q., Camp Geck and the U.S. Weather Office at Meeks Field were all linked by the teletype network set up by the Americans, so that each office received all the meteorological information teletyped from any other office.

The Collection and Dissemination of Data

Network of Reporting Stations : The existing Icelandic meteorological network was the basis of the synoptic reporting organisation throughout the occupation. In August 1941, there were seven main synoptic reporting stations (excluding those manned by R.A.F. or U.S. personnel) and 22 subsidiary stations ; the subsidiary stations had increased to 26 by 1945. At first, the main synoptic stations reported at the four main synoptic hours only, but it was arranged in June 1941 for each station to send as many synoptic reports as possible, *i.e.*, every three hours, at 0000, 0300, 0600, 0900 G.M.T. The reports were telephoned or telegraphed direct to the H.Q. of the Icelandic Meteorological Service, who passed them to the adjacent R.A.F. meteorological office for further distribution. Reports from two of the subsidiary stations (Horn and Grimsey) were sent partly by wireless, and the necessary pad cyphers were provided for encyphering the reports. International Code was used for reports which were sent wholly by land-line. The basic reports from the Icelandic stations were supplemented by hourly observations throughout the 24 hours from each of the R.A.F. meteorological offices on airfields. A similar procedure was adopted by the U.S. Services.

The U.S. Weather service set up a radio-sonde station at Reykjavik airfield in September 1941. Ascents were normally made twice daily. The data thus made available filled a long felt want, as upper air information from Iceland was of the utmost value, not only to the meteorological services in Iceland but to the Allied forecasting services generally.

Jan Mayen : Norwegian meteorological personnel were evacuated from Jan Mayen in September 1940 as their position was expected to become untenable, but in January 1941 it was decided to re-open a meteorological station on the island as it occupied a key position in the empty Arctic seas. The station was a Norwegian responsibility and was maintained from Iceland ; the meteorological staff chosen were Norwegian civilians. All possible help was given by the R.A.F. meteorological service in Iceland, in respect of stores, instruments and cyphers.

The meteorological station on Jan Mayen began reporting again early in 1941. Synoptic reports for the four main hours were transmitted on a low-power transmitter to Iceland, but reception was irregular and many reports were received late. In August 1941, suggestions were made for improving the regularity of the reports and in September it was arranged for reports to be supplied at all the eight synoptic hours. It was decided in October that the Jan Mayen reports should be made 15 minutes before each synoptic hour, thus providing more time for the reports to be included in the synoptic collective broadcasts from Iceland. It was possible, thereafter, to include an average of 50 per cent of the Jan Mayen reports in the Iceland collective broadcast for the same synoptic hour. The number of reports received also increased to almost 100 per cent.

With the approach of D Day, it was decided to set up a radio-sonde station at Jan Mayen, to supply the Allied meteorological services with adequate upper air data from the polar region to the north of Iceland. The equipment was supplied from the United Kingdom, together with a R.A.F. specialist Signals officer to supervise installation of the radio transmitting apparatus. An American radio-sonde technician also went to Jan Mayen to help the Norwegian radio-sonde personnel during the early ascents. Difficulty was experienced at first with the humidity element calibrations, but the radio-sonde station functioned smoothly soon after D Day. Ascents were made twice daily and the results were transmitted to Iceland for inclusion in the collective broadcasts and for transmission to the United Kingdom on point-to-point channels.

An automatic German weather reporting station was discovered in the north of Jan Mayen during 1945 and was dismantled by the Norwegians.

The W/T equipment on the island consisted of a British Army No. 11 receiver and transmitter (20 watts) and a R.A.F. 1084 receiver and R.A.F. 1154 transmitter (100 watts). A point-to-point watch was kept with No. 2 W/T Section Iceland Force Signals (Army) at 01, 07, 13 and 18 G.M.T. on frequency 6,220 kcs. Atmospheric conditions, however, often made reception in Iceland difficult or impossible. In May 1942, after the withdrawal of British Army Forces in Iceland, the R.A.F. assumed responsibility for communications with Jan Mayen. Several R.A.F. stations in Iceland would listen for the Jan Mayen transmissions, but reception was usually best at Akureyri.

Collective Broadcasts : When the British meteorological officer landed in May 1940, it was at once arranged with the Director of the Icelandic Meteorological Service and with the Marine Chief Signals Officer for all the regular Icelandic collective messages to be cabled to the United Kingdom with Most Immediate Priority. Normally, the information was received at the Central Forecasting within about an hour of dispatch. It was so vital to withhold the Iceland reports from the enemy that the transmissions by cable were continued

until the summer of 1941 when pad cyphers became available. During June and July 1941, the collectives were passed to H.Q. No. 15 Group by a W/T point-to-point channel, and on 26 July wireless synoptic broadcasts from Iceland were recommenced. The broadcasts were made at 30 minutes past the synoptic hour by the British Army transmitting station at Vatnsendi. The wireless broadcasts were received satisfactorily in the United Kingdom and the transmissions by cable were then stopped. The R.A.F. meteorological office in Reykjavik Town obtained the reports from the H.Q. of the Icelandic Meteorological Service, encyphered them and passed them by telephone to the transmitting station.

In April 1942, because the British Army W/T station at Vatnsendi was closing down, it was arranged for the collective synoptic broadcasts to be made on the Iceland—Prestwick W/T auto-circuit at hand speed. The new procedure began on 6 May 1942. At about that time, there was some controversy with the U.S. authorities regarding collective transmissions from Iceland. Radio-sonde observations were added to the collective messages when available, and from June 1942 weather reports from aircraft and meteorological reconnaissance reports were included.

In February 1943, the broadcasts at the main synoptic hours were divided into two parts, Part 1 containing surface reports from a selection of about seven stations, and Part 2 the remaining data. This enabled other transmitters to repeat Part 1 in the form in which it was received, *e.g.*, in the ETA broadcasts and Fleet Synoptic Broadcasts. On 7 November 1944, weather reports from Meeks Field and Holar were included in Part 1 of the Iceland Synoptic Broadcast and the broadcasts at 0300, 0930, 1530 and 2130 G.M.T. were also sent in two parts as at main hours.[1]

Receipt of Synoptic Data : The lack of synoptic data at first made forecasting in Iceland much more difficult. A fair cover over the United Kingdom was obtained by intercepting British Fleet Synoptic broadcasts but almost no information was available over the Atlantic and the land areas to the west of Iceland. Reports in International Code from stations in Greenland, Spitzbergen and Bear Island were occasionally picked up in 1940.

The occasional broadcasts in International Code from Greenland ceased in September 1940. Cyphers were dropped by aircraft from Iceland on two Greenland reporting stations, with the request that they resume broadcasting in cypher, but few messages were received. Preliminary arrangements were made for an expedition to visit the country to arrange for regular meteorological broadcasts from the Danish observers known to be still there, but as the United States had already started to set up a network of reporting stations in Greenland, the proposed expedition was abandoned.

From 5 July 1940 until the beginning of October 1941, the Air Ministry cabled synoptic reports from the United Kingdom and Canada in order to supplement the Fleet Synoptic broadcasts.

The amount of data received improved greatly towards the end of 1941. In September, Air Ministry meteorological broadcasts (ALFIG) were intercepted instead of the Fleet Synoptic messages. Information from the west continued to be scanty but North American broadcasts were occasionally intercepted, and the data sometimes obtained from one of the U.S. meteorological offices. The number and frequency of reports from Greenland also improved greatly.

[1] A.M. File S.59739/II.

Closer contact with aircrews and the increase in air operations resulted in an increase of in-flight and post-flight weather reports which proved to be of great value.

During 1942, the Greenland synoptic reports were received with greater reliability in Iceland than in the United Kingdom. They were obtained in Iceland partly by direct reception of synoptic broadcasts from Greenland and partly through U.S. Army W/T channels. It was, therefore, arranged for the Greenland reports to be passed to Prestwick on the Iceland—Prestwick W/T channel as soon as received. In October, the synoptic reports from four Greenland stations were cabled to London as soon as they were received in Iceland.

Reports from a ship *Baker*, an American vessel which kept almost stationary watch around 63° N. 31° W., started in the summer of 1942 but the ship was withdrawn in December 1942. A similar arrangement was followed in 1943 but from March 1944, the ship continued in position until after August 1945. Operated by the U.S. Coastguard Service, it also acted as an Air Sea Rescue vessel. The *Baker* reports, made every three hours, were of the utmost value as they gave the sole indication of the pressure tendencies to the south-west and enabled the forecasters in Iceland to give earlier warning of the deterioration of visibility of lowering of cloud base so that Operations Staff could recall aircraft or take diversion action.

Meteorological Reconnaissance Flights : Three Hudson aircraft of No. 1407 (Met.) Flight arrived in Reykjavik in April 1942 and began a routine of one sortie per day on a track of 225 degrees from base a week after arrival. The length of the sorties was at first 250 miles from base, but this was extended to 350 miles later in the month. One sortie per day was regularly maintained until October 1942, but from then until April 1943, unfavourable weather and lack of serviceable aircraft made the sorties very irregular.

Regular flights were resumed in May 1943. In August the length of the sortie was increased to 400 miles and in November 1943 to 500 miles. The outward flight was at a level of 950 mb., a sounding was made at the terminal position and the return flight was made at the 500 mb. level. Absolute reliance was often placed on reports from the Met. Flight before the establishment of the American ship *Baker*, because of the absence of ships' reports or any other source of information to the south-west, a direction from which violent storms, low cloud and poor visibility invariably approached. The planning of important operations often awaited the receipt of these vital observations, which were transmitted by the aircraft to base as soon as they were made.

No. 1407 (Met.) Flight was replaced by No. 251 Squadron in August 1944. In March 1945, two accidents ended the meteorological work of the Hudson aircraft of No. 251 Squadron. Until this squadron was converted to Fortress aircraft, No. 53 (Liberator) Squadron flew the meteorological sortie carrying a meteorological air observer. From 22 May No. 251 Squadron operated with Fortress aircraft on a new triangular track of 350 nautical miles at 950 mb. on 210° course from Reykjavik, 200 nautical miles at 500 mb. on 330° course and return to base on course 063°.

The U.S.A.A.F. also operated a Met. Reconnaissance Flight which flew along a track determined by the U.S.A.A.F. Weather Officer. The British and U.S. Reconnaissance Flights were used to best advantage and did not overlap in any way.

Meteorological Services for the R.A.F.

Operational : At first there was little demand for forecasts as almost the only flying consisted of fair weather flying by Walrus aircraft, scattered around the island at Reykjavik, Akureyri and Seydisfordour, and the necessary forecasts were telephoned. Isolated Sunderlands visited Iceland, however, and needed forecasts for return flights to the United Kingdom. In addition to forecasts, warnings (particularly gale warnings) were issued to all interested parties.

Liaison was at first maintained with the only other R.A.F. officer on the island (who had been interned after making a forced landing) and visits were made with him to potential airfield sites, and appropriate climatological advice was given. Little constructive organisation was possible at that stage, and the Vedurstofan organisation proved good and co-operative enough to need very little modification to meet the limited demands of the British Forces.

In July 1940, Air Ministry asked for advisory forecasts to be provided to No. 18 Group for the forthcoming move of No. 98 (Battle) Squadron from Wick to Kaldadarnes. These forecasts were for the final leg to Iceland, with landing forecasts for Reykjavik and Kaldadarnes. The restricted range of the aircraft demanded very accurate forecasting and a successful flight depended on meeting no adverse winds. A further difficulty was the lack of diversion airfields in the event of Reykjavik and Kaldadarnes being unfit together, as was generally the case in a warm, moist south-westerly air stream. The aircraft were flown to Iceland in two flights on different days ; forecasts were sent for approximately one month before the operation was completed.

The experience gained during the winter of 1940–41 enabled the forecasters to warn Air Staff of the exceptionally severe gales which must be expected during the Icelandic winter. As a result, the R.A.F. flying boat squadrons were withdrawn from Iceland from the winter of 1941–42 and the Norwegian float plane squadron beached before the winter weather set in. The wisdom of this decision was shown by the American loss of two complete flying boat squadrons, destroyed at their moorings in a gale during the first part of the winter. Naturally, there was a large seasonal fluctuation in operational activity from Iceland. This did not affect the general meteorological routine, but it did affect the number of briefings and the preparation of operational flight forecasts.

The A.O.C. Iceland, asked, in September 1942, for hourly broadcasts of weather information to operational aircraft in flight. Arrangements were made for forecasts of weather at Reykjavik and Kaldadarnes to be transmitted hourly from Reykjavik on the operational frequency. The period covered by each broadcast was two hours from time of broadcast and a specially devised letter code was used. The broadcasts began on 1 January 1943 and continued throughout the period under consideration without interruption. Reception of these broadcasts by aircraft in flight was good, except in an area to the south-east of Iceland, and to rectify this, the broadcasts were repeated from the W/T station at Hofn from March 1943. The scheme was much appreciated by aircrews and was continued with slight modification until the end of the war.

A new phase opened in May 1943 when very long-range Liberators began to operate from Icelandic airfields. In order to meet adequately the Meteorological needs of these flights, a frequent exchange of landing forecasts for a period

of 24 hours ahead was initiated between forecasting offices in Iceland, the United Kingdom, Newfoundland and Canada, to cover bases in these countries. On the basis of the forecasts so provided, the Operations Staff could make advanced plans.

Transport and Delivery Flights : An appreciation of the meteorological facilities required in Iceland for large scale delivery flights from North America to the United Kingdom via Iceland, and possibly Greenland, was prepared in the winter of 1940–41 for R.A.F. Headquarters. In this connection, the Senior Meteorological Officer visited the United Kingdom in February for consultations at Air Ministry and at O.A.M.C.U. (Overseas Air Movement Control Unit), Gloucester.

The first transatlantic flight from Iceland was to Newfoundland in July 1941. In order to prepare forecasts for this flight, synoptic data and advisory forecasts were obtained from Newfoundland via O.A.M.C.U.

A regular air transport service was set up between Prestwick and Reykjavik in the latter half of 1941, the requirements of these flights being met by a regular inter-change of information between Reykjavik and O.A.M.C.U. Gloucester (later T.A.C., Prestwick). Advisory forecasts for occasional flights from Iceland to North America (some via Greenland) were obtained from Newfoundland via O.A.M.C.U. Gloucester.

It became known in March 1942 that the route Canada—United Kingdom via Greenland and Iceland, termed the N.E. Ferry Route by the Americans, was to be developed for the large-scale delivery of aircraft to the United Kingdom. Preparatory conferences were held at Reykjavik with U.S.A.A.F. representatives in March and April 1942. The main flow of aircraft began in May ; it increased in the summer months and in July, 265 flight forecasts for non-operational flights were issued at Reykjavik. Many of the aircraft flown through Iceland were single-seater fighters flying in visual contact with a leading bomber. In such cases, a full flight forecast was issued to the leading bomber only, and the number of aircraft flown through Iceland was therefore considerably more than the number of flight forecasts issued. The fighter pilots were given a copy of the pictorial forecast for the flight ; this diagram was part of the full flight forecast. The flow decreased with the onset of winter and there was a marked drop in the delivery traffic in January and February 1943. This was followed by an increase in the spring and, in April 1943, 128 flight forecasts were issued for non-operational flights.

To meet the forecasting requirements of the non-operational overseas flights, a provisional procedure for routine interchange of route and landing forecasts and other meteorological information was introduced in May 1942 for flights between Reykjavik and United Kingdom (Prestwick) and between Reykjavik and Greenland (B.W.1) and in July 1942 for flights between Reykjavik and Canada (Dorval). In October, an official ' M.O.O.F.' procedure was introduced for the routes from Iceland to the United Kingdom and to Canada.

The arrangements for ferrying aircraft through Iceland for delivery to the R.A.F. were the responsibility of R.A.F. Ferry Command (later Transport Command), which, in September 1942, established a new Area Control named North Atlantic Control (N.A.C.) at Reykjavik airfield. The meteorological office on the airfield worked very closely with N.A.C. and arrangements were made for it to move from the Operations Block to a new N.A.C. building.

After Transport Command took over the work of Ferry Command in March 1943, the meteorological facilities provided in Iceland for transport and delivery flights conformed with the general Meteorological Office arrangements for providing meteorological information to the aircrews of Transport Command in all areas.

The ferrying in the summer of 1944 of a number of Catalina aircraft from Gander in Newfoundland to Murmansk in Russia via Reykjavik required special meteorological arrangements. A complete meteorological organisation for this operation was drawn up on the lines of the M.O.O.F. procedure. Preliminary and final advisory flight and landing forecasts for the route Reykjavik—Murmansk were received in M.O.O.F. code from Murmansk. As the aircraft were flown by Russian crews, a Russian meteorologist was attached to the meteorological office, Reykjavik, to help to prepare the forecasts and to brief the crews. A R.A.F. interpreter officiated at all discussions and typed the forecasts in Russian. The operation lasted from the end of May until mid-August.

Meteorological Services for the Navy and Army

The meteorological information required by the Navy was mainly in the form of area forecasts and was supplied to the naval authorities at A.C.H.Q. For the short time that F.A.A. aircraft were stationed at Akureyri in 1940, forecasts were supplied from Reykjavik and later from the meteorological office at Akureyri. At the request of the R.N. authorities at A.C.H.Q., Iceland, arrangements were made for the Iceland collective broadcasts for the main synoptic hours to be encoded at the Vedurstofan office in Reykjavik and passed to R.N. Signals at A.C.H.Q. for re-broadcast on the Naval ' Port Wave.' These Fleet Synoptic began on 13 February 1943 and continued until 1 June 1945.

The meteorological requirements of the Army were confined to general forecasts and artillery Meteor reports. These were supplied to Army units from the most convenient meteorological office. In the winter of 1940–41, meteorological personnel were attached to artillery units on several occasions during exercises.

Co-operation with Other Meteorological Services

Icelandic Meteorological Service : A lesson clearly shown in Iceland as elsewhere was the invaluable aid which the local meteorological service of a country can give to occupying forces, if the co-operation of that Service can be enlisted. Without this co-operation in Iceland, a R.A.F. network of synoptic reporting stations would have had to be set up, a task presenting formidable difficulties. It was early agreed that the British Government should continue to pay the Icelandic Government the financial contribution previously paid by the International Meteorological Organisation, and should also pay for a number of extra observations made by civilian Icelandic reporting stations at the request of the R.A.F. Meteorological Service in Iceland.

United States Weather Services : A detachment of the United States Navy arrived in Iceland in April 1941 ; contact was immediately established with their meteorological staff and they were supplied with all available information. Later in the year, the United States Army and Navy both set up meteorological

offices on or near R.A.F. Station, Reykjavik, and close liaison was maintained with both these offices. There was a full and complete interchange of information.

The American meteorologists were not experienced in forecasting for long overseas flights and, at the request of the U.S. authorities, the R.A.F. meteorological office at Reykjavik airfield at first met the forecasting requirements of U.S. as well as R.A.F. aircraft operating on the N.E. Ferry Route ; the U.S. Army Weather Office continued to meet the meteorological requirements of the U.S. Fighter squadrons based in Iceland for local defence. In August 1942, U.S. aircraft began to use a new airfield, Patterson Field, and meteorological briefings were given by a R.A.F. forecaster who travelled from Reykjavik with the completed forecast documents. Later, the Americans used another airfield, Meeks Field, adjacent to Patterson Field, and a U.S. Weather Office was set up there in April 1943. U.S.A.A.F. forecasters then took over from the British the forecasting for overseas flights by U.S. aircraft to the United Kingdom, North America and Greenland.

From March 1942 until January 1943, there was some difficulty between the British and U.S. Meteorological Offices in Iceland on the question of the security of weather reports sent by W/T from Iceland. The instructions issued to the U.S. Weather Offices in Iceland often resulted in meteorological information being sent in clear or in codes other than those issued by the Air Ministry for the purpose, and usually of a lower security standard.

The U.S. Navy Weather Office closed down in the autumn of 1943 when the U.S. Navy Squadron was withdrawn.

Co-operation with the U.S.A.A.F. Weather Office was very close in the later stages of the war. Daily routine telephone conferences were held to discuss current synoptic charts, and there was a routine exchange of meteorological information by the meteorological teleprinter network. The British meteorological office normally supplied the Americans with British and some continental reports while the Americans supplied the British with American and Greenland reports. On 20 October 1944, it was agreed with the U.S.A.A.F. that three Americans should be posted to the meteorological office in Reykjavik town to encypher Icelandic reports for broadcasts to America. These personnel were withdrawn on 26 May 1945 when encyphering became unnecessary in that area.[1]

The Faeroes

Organisation

The need for a meteorological office in the Faeroe Islands arose from the decision to build a flying boat base and aerodrome on the island of Vaagar. On 17 April 1942, Coastal Command asked Air Ministry to provide meteorological staff and the Treasury approved the establishment of a Type 2 meteorological office.[2]

In the absence of teleprinter communication, the Director of Signals was asked to make provision for the following W/T requirements :—

(*a*) Reception of ETA broadcasts at 0230, 0500, 0830, 1100, 1430, 1700, 1930 and 2300, each transmission occupying 20–30 minutes.

[1] A.M. File S.59739/II.

[2] A.M. File S.79660.

(*b*) Reception of Iceland broadcasts at 0130, 0430, 0730, 1030, 1330, 1630, 1830, 2230.

(*c*) Transmission of reports to the United Kingdom at five minutes past every hour, throughout the 24 hours.

Reception from U.K. or Iceland at times other than those in (*a*) and (*b*) might also be needed. Arrangements were made to provide the necessary British and American cyphers.

It was agreed with Coastal Command that normal meteorological office accommodation would be provided in the Operations Block, together with an office and annexe in the Watch Office, and that all staff would be in R.A.F. uniform.

Meteorological staff (two officers and three O.R.s) arrived at Sorvage Vatn, Vaagar, on 8 July 1942. The lay-out of the station itself was as yet purely temporary and on a different site from the proposed Operations Block, on which work had not yet started. A site at the head of the lake (Sorvage Vatn) was adapted to serve as a temporary base for flying boats. The meteorological section began work by erecting a tent to serve as an office. A site was chosen for an instrument enclosure and for more permanent accommodation (Nissen hut) at the head of the lake near the east bank of the river. The choice was governed by the following factors :—

(*a*) Availability of ground : only 30 per cent of the land in the Faeroes is suitable for grazing and the R.A.F. was reluctant to use land which might be used for this purpose.

(*b*) Field of View : this was very restricted in most places. Only a site near the river afforded a clear view up and down the main valley. Other sites were markedly inferior in this respect.

(*c*) Proximity to Signals Section : this restricted the site to the head of the lake.

(*d*) Proximity to Operations Room : the temporary Operations Room was ¼ mile from the head of the lake, on its eastern bank. As a site for a meteorological office it was manifestly unsuitable.

The original office was a small tent erected near the signals trailer for convenience in the dispatch of messages. To work satisfactorily under such conditions was difficult and efforts were made to have a Nissen hut built on a site near the river bank. Meanwhile, it was fortunately found possible to occupy the top room of a nearby house. Within two months of the original request, the Nissen hut was ready and occupied. Specially large windows permitted easy check on weather conditions.

It was found that the arrangements for W/T facilities existed only on paper, and the facilities available bore no resemblance to those planned. The Signals Officer was short of supplies of every kind, but was eventually able to allot an aircraft receiver (R.1082) and a duty operator for the reception of meteorological messages. Outgoing messages were cleared by the only means available —the point-to-point administrative channel to H.Q. No. 18 Group. The large amount of priority traffic and numerous breakdowns in communication made delays inevitable. When the meteorological office moved to the Nissen hut, there was enough space to permit of its own signals section and the Signals

Office was persuaded to allow all meteorological traffic to be received in the meteorological office. The wireless operator thus came under the immediate control of the duty forecaster. With time, communications improved and superior wireless receivers were allotted for reception of meteorological data, but the reception of the Iceland broadcasts continued to be most unsatisfactory.

Hourly observations in an abbreviated code were begun at 1200 hours on 10 July 1942, the period of observation being 0700–2200 daily. Messages were transmitted to Air Ministry and H.Q. No. 18 Group in the W/T point-to-point channel with H.Q. No. 18 Group. A programme of full synoptic observations throughout the 24 hours was begun at 1600 hours on 18 July 1942. Pilot balloon and nephoscope observations were not made at fixed times but as and when weather conditions permitted. A.A. Meteor reports were supplied regularly to No. 290 A.A. Battery. Except in the very early days, all main synoptic charts were drawn, and local forecasts issued, despite the inadequacy of the staff. A weather diary was maintained by the forecaster and daily synopses of weather prepared.

Provision of a Network of Reporting Stations

The question of providing satellite reporting stations had been discussed at Air Ministry before the establishment of the station. It had been decided that such stations should be organised, by employing local observers if necessary.

It became clear very early that personnel at radar stations were in the best position to furnish routine weather reports. These stations were being set up in isolated points about the islands and were in touch with R.A.F. Station, Vaagar, by short wave W/T. The Station Commander approved a proposal to use radar personnel as weather observers. The airmen were given preliminary training in meteorological observing before they were posted to the radar stations. The positions of the proposed reporting stations were as follows :—

Mykines	62° 06′ N.	7° 38′ W.
Eide	62° 19′ N.	7° 05′ W.
Nolsoy	61° 57′ N.	6° 36′ W.
Sand	61° 52′ N.	6° 54′ W.
Akraberg	61° 24′ N.	6° 40′ W.

As an interim measure, typescript instructions were issued, but standard meteorological publications were later issued. Messages were encyphered in one-time pad before transmission. Reports were, on the whole, satisfactory and very useful. The policy in respect of the radar stations was revised in January 1943 when it was considered enough to receive from these stations deterioration reports and reports on request. This decision was taken in order to relieve the amount of radar signals traffic and to avoid overwork of voluntary observing personnel.

In August 1942, the Meteorological Officer-in-Charge visited the pre-war reporting station maintained by the Danish Government at Thorshavn and recommended that Air Ministry should take over responsibility for the station. This recommendation was accepted. It involved an arrangement with the Great Northern Telegraph Company and payment of its representatives at the station and equipping the station to the scale of a British reporting station.

The installation of equipment and preliminary training of observers was completed by May 1943. It was also arranged that, as soon as communications improved, routine observations from Thorshavn would be passed to the meteorological office at Vaagar. The arrangement, which later came into force, was that the observations were telephoned to the Information, Thorshavn, and, after encyphering, were transmitted to Vaagar by W/T. Previously, Vaagar had been dependent on ETA broadcasts for reception of the Thorshavn reports. In March 1944 a telephone link was set up via exchanges at Vaagar and Thorshavn.

In addition to Thorshavn, subsidiary stations giving plain language reports were maintained by the lighthouse keepers at Mykenes, Akraberg and Nolsoy. In peace-time, these reports were broadcast by wireless for the benefit of shipping. The war-time practice was to collect a register of observations from each station monthly. Lack of communications made it impossible to use these reports.

Three more fully equipped stations in the Faeroes were discovered during 1943, each capable of carrying out full synoptic observations. The stations were Hvalvik, near the narrow channel between Streymoy and Esturoy; Hoyvik, about two miles N.N.E. of Thorshavn, on the coast; Sand, at Sand on the island of Sand. The stations were at experimental farms maintained by the Central Agricultural Institute at Aalborg; Hoyvik was the only station to be visited.

Closing of Meteorological Office

It became clear as early as April 1943 that Vaagar was unlikely to be used except as an advanced base for emergency landings, and the meteorological officer suggested closing the meteorological station, but H.Q. Coastal Command insisted on the need to keep a forecasting officer at Vaagar as aircraft were still likely to be diverted there.[1] On 1 February 1944 it was agreed to withdraw the forecaster on the assumption that he would be available at H.Q. No. 18 Group for advice concerning diversions. H.Q. Coastal Command notified Air Ministry on 22 March 1944 of the withdrawal of all R.A.F. personnel and equipment from the Faeroes.

Services for the Royal Air Force

For most of the period, meteorological services for the R.A.F. were restricted to the issue of local forecasts and occasional landing forecasts. No squadrons were ever permanently based on Vaagar and the only operational activity was occasioned by visiting flying boats. Visits by aircraft were spasmodic during 1942, during January and February 1943 there was no activity at all, and it was not until May that Vaagar began to serve a purpose as an advanced base, and an alternative to Sullom Voe when that station was unfit. During this period of comparative activity in the summer of 1943, forecasts were regularly issued for areas adjacent to the islands and for the routes Vaagar—Sullom Voe, Vaagar—Oban. On a few occasions, forecasts were also given for flights to Iceland and for sorties in the Norwegian Sea.

[1] A.M. File S.79660.

The Weather Factor in Operations from Vaagar

The following approaches to R.A.F. Station, Vaagar, were used by aircraft :—

(*a*) *Southern Approach* (*Waterfall*) : Flanked on the east by Rituberg (1,220 feet) and on the west by a ridge reaching 820 feet.

(*b*) *South Eastern Approach* (*Midvag Valley*) : Flanked on the south by the northern slope of Rituberg and on the north by the southern spur of Reynsatindur.

(*c*) *Western Approach* (*Sorvag Valley*) : Sorvag fjord is flanked on the north by peaks up to 2,300 feet.

After discussions with pilots, the following conclusions were reached :—

(*a*) With northerly or north-easterly winds the waterfall approach could be used even with very low cloud (400–600 feet) but only by experienced crews who had visited the place before. With westerly winds the waterfall approach should never be used, in view of the large variations of wind over the southern part of Sorvags Vatn.

(*b*) The Midvag approach was regarded as a good one for all winds between north and west and inexperienced crews should always use it in preference to the waterfall if low cloud was present.

(*c*) With easterly or westerly winds of over 20 m.p.h., it might be unsafe to land on Sorvags Vatn and Sorvag Fjord should be used.

Taking weather conditions as a whole, Midvag and Sorvag were undoubtedly regarded as the best approaches; the greatest caution had to be exercised with cross-winds over 20 m.p.h.

Apart from the effects of winds on the approach, the principal weather difficulties were :

(*a*) Sudden deteriorations difficult to foresee with the aid of a weather chart in an area of few reporting stations and uncertain W/T reception.

(*b*) Aircraft icing in winter when, although extremes of temperature are not usual, the average daily minima approximate to freezing point and the average daily minimum temperature at 2,000 feet is probably well below it. This is important as the long sea track of the air results in large amounts of moisture being available for ice formation.

(*c*) Down currents in the neighbourhood of high ground, experienced with strong winds.

Forecasting Problems

Successful forecasting in the Faeroe Islands depends largely on the regular and prompt supply of weather data from the Icelandic and Greenland stations and from the Atlantic ocean, a condition which was never fulfilled during the history of the station. During the first few days of operation it was very difficult to maintain a sequence of charts. The Air Ministry and Iceland broadcasts were received in fragmentary form. Reception of the Air Ministry issues later became regular and, after the Alfig issues were introduced, at least two Iceland stations were received from that source. Direct reception from Iceland was always rather uncertain, especially during the summer months, but the data in these broadcasts were vital to successful forecasting at Vaagar.

At various times, Air Ministry were asked to provide more basic data over the Atlantic but very little improvement was ever effected. The forecaster at Vaagar was, therefore, largely dependent upon the analyses put out by the Central Forecasting Office in the United Kingdom for assessing the large scale variations of weather. Vaagar, being situated in the track of the main cyclonic systems, experienced large scale variations of weather very rapidly and these were difficult to time.

It was realised that orography would result in very great local variations of weather in the Faeroes and that a knowledge of these would be of great importance. For that reason, satellite reporting stations were established at points around the islands.

CHAPTER 26

THE ATLANTIC

The Azores[1]

Organisation[2]

An agreement made between the British and Portuguese Governments in the summer of 1943 provided the former with certain facilities in the Portuguese-owned islands of the Azores. As a result, British forces were sent to the Azores and arrived on 7 October 1943. The force included a meteorological unit consisting of one squadron leader, three flight lieutenants and nine other ranks. By the end of the war in Europe, the unit had increased to eight officers and 20 other ranks. The original party carried a minimum of equipment, consisting of an aneroid barometer, a Kew pattern barometer, a small screen, pilot balloons, theodolite, hydrogen, maps, charts and stationery requisites.

The site chosen for the meteorological office was on a small Portuguese airfield (Lagens), in a landfault in the north-east of the island of Terceira. The facilities of this airfield were quite inadequate to house the British forces; there was one completed stone building with about five rooms and four unfinished stone buildings. As a result, most of the administrative offices were in tents for some time after the landing and most of the staff also lived under canvas. It was decided to use for the operational sections the one complete stone building in which an Operations Room was set up, and accommodation allotted to Intelligence, Signals, Cyphers and Meteorology. The meteorological accommodation consisted of half a room about 15 feet square, the other half being occupied by Cyphers, which was quite inadequate. Buildings were erected as quickly as possible, but it was not until April 1944 that the meteorological unit had accommodation which even approached the minimum needs. By that time, additional accommodation had been built by the British Forces, and the meteorological unit moved into a Nissen hut which communicated with the Operations Room on one side and Flying Control on the other. The hut was divided into three rooms—a forecast room 24 feet by 16 feet and two smaller rooms, each 12 feet by 8 feet; additional accommodation in a wooden hut nearby was later available.

Apart from the question of accommodation, the main problem was collecting synoptic data. Before leaving England, it had been arranged to supply enough W/T personnel and equipment to intercept the meteorological transmission from Air Ministry (GFA), New York (WSY), New Orleans (WEK) and to take the smaller collective messages from Spanish, Portuguese and N.W. African stations. It was some time, however, before the necessary aerials, power supply, etc., could be established on Lagens airfield, and temporary arrangements were made until the permanent equipment was installed. Unfortunately, the temporary aerials were very badly screened by mountains and reception

[1] *See* Appendix 17 for a map showing the meteorological stations in the Azores.
[2] A.M. File S.97238.

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of GFA and WSY was very poor. At first, the best reception was from WEK; that from Lisbon (CTX) was indifferent. The Madrid (ECA) transmissions were very poorly received throughout the stay in the Azores. One of the most surprising difficulties in collecting synoptic reports was in the reception of the Azores collective itself. Although CTH, the transmitting station at Horta, was only 80 miles away, reception of the meteorological transmission was very bad indeed, and for a considerable time after the establishment of the meteorological office at Lagens, the Azores reports were received by telephone from the Portuguese meteorological office at Angra do Heroismo, where reception of Horta was very regular. Language proved a difficulty and some of the Portuguese had to be taught to count up to nine in English, and all the British staff to count up to nine in Portuguese. At a later stage, a submarine cable was laid from the R.N. station at Horta to the British H.Q. at Lagens, and the Azores observations were then received on that channel.

The original principle of relying on interception for synoptic data was maintained for about a year; but the later development of the airfield as a staging post for transatlantic flying made improved arrangements necessary and special meteorological point-to-point W/T circuits to Prestwick and Dorval were installed in June and July 1944 respectively. Using these channels, the United Kingdom and Iceland data were received from Prestwick and Greenland, and the North American and Caribbean data, plus Atlantic ship reports from Dorval. Interception of Lisbon, North Africa, Madeira and Canaries data was continued.

Expansion of Network of Reporting Stations

The Portuguese Government had maintained a number of meteorological reporting stations in the Azores for many years, but they were not well sited from the point of view of flying operations, and they were not, of course, under Air Ministry control. Efforts were made, therefore, as opportunity occurred, to open other observing stations besides Lagens. In the autumn of 1944, the Portuguese authorities were persuaded to adopt the revised synoptic reporting times of 0000, 0600, etc., G.M.T., and the new procedure was put into effect at Portuguese-controlled stations from 1 October 1944.

An airfield was developed near the village of Sant 'Ana on the north coast of San Miguel and a small R.A.F. unit was established there to provide diversion facilities for all aircraft using the Azores. The opportunity was taken to set up an auxiliary reporting station at Sant 'Ana. Equipment consisted of an aneroid barometer and a small screen containing wet and dry bulb thermometers. The station was set up by a meteorological officer from Lagens who sited the screen, chose visibility points and instructed the R.A.F. personnel on making observations. Observations were made at the standard synoptic hours and hourly on request; unfortunately, no standard anemometer was available, and winds were estimated. Routine inspections were made at the station by a member of the meteorological office from Lagens. The standard of reporting was good, observations being received regularly, and the keenest interest was shown by the R.A.F. personnel concerned.

The advantages of receiving meteorological observations from Santa Maria had long been appreciated by Portuguese meteorologists, and efforts had previously been made to set up a Portuguese station there, but a shortage of

funds had made these unsuccessful. With the establishment of a U.S. air base on the island in August 1944, a U.S. Weather Office was set up and hourly observations were made and transmitted to Lagens.

The Portuguese network of reporting stations in the Azores suffered from the similarity of their exposures, all of them being sheltered from north and north-west winds. The two British airfields, Lagens and Sant 'Ana were both sheltered from south and south-west, but were exposed to north and north-west winds. As there was no station in the islands west of Terceira with a north or north-west exposure, it was decided to try to set up at least one station west of Lagens with a similar exposure. To this end, negotiations were opened with the Portuguese. Two sites were considered: one at a lighthouse on the north coast of San Jorge, the other at the radio station on the little island of Corvo north of Flores, but the whole subject was later dropped.

On VE Day, the network of observing stations in the Azores was as follows:—

Portuguese Civilian ..	Ponta Delgada, Angra do Heroismo, Fayal, Santa Cruz.
Portuguese Navy ..	Fayal, Lagens (Flores).
British	Sant 'Ana, Lagens (Terceira).
U.S.A.T.C.	Santa Maria, Lagens (Terceira).

Upper Air Information

The *Carimare*, a French meteorological observing ship, commissioned just before the war, had visited Angra do Heroismo during its cruise in the North Atlantic. The visit influenced Col. Agostinho, the Director of the Meteorological Service in the Azores, in his plans for a new observatory at Angra, which allowed for the installation of radio-sonde of a French pattern. The installation was completed and a few ascents were made, but during the war, the Portuguese were unable to obtain the accessories and no ascents were made at Angra while the British forces were in the Azores.

The necessity for upper air information was recognised, and even before the British force left the United Kingdom, attempts were made to arrange for observations either by aircraft or radio-sonde. As the completion of any such plans was expected to be delayed, local arrangements were made for aircraft of the operational squadrons based in the Azores to make ascents over the airfield at the request of the Senior Meteorological Officer. The equipment available was not satisfactory; it consisted solely of a Mark I strut psychrometer loaned by the Portuguese. As different aircraft were used for the ascents, the psychrometer could not be properly mounted and the best that could be done was to lower the psychrometer through an aperture in the floor of the fuselage. An aneroid barometer reading from 400–1,050 mb. compensated for temperature was also loaned by the Portuguese, and with this equipment, a number of ascents were made late in 1943 by Fortress aircraft of Nos. 206 and 220 Squadrons. As the aircraft were not fitted with oxygen, the nominal maximum altitude was 10,000 feet but this height was usually exceeded and the highest altitude reached was 17,600 feet.

Pan-American Airways had set up a radio-sonde station at Fayal, and ascents were made there intermittently. Considerable difficulty was experienced in obtaining these readings but, ultimately, it was arranged for the messages to be relayed to Lagens by the Royal Navy at Fayal.

The American Weather Office at Lagens set up a radio-sonde station there with the utmost speed after its arrival in December 1943 and from then on two ascents daily were made using standard U.S. Army equipment.

Eventually, the Air Ministry decided to set up a high altitude flight at Lagens. Spitfires of No. 269 Squadron were earmarked for this purpose and were brought out to Lagens late in 1944, but the aircraft were fitted with guns which considerably restricted their ceiling. Further, they were not tropicalised, and there was more delay in obtaining necessary equipment. At first, serviceability was low, but soon two ascents were made daily except in very bad weather. The thermometers carried were of the mercury-in-steel type, but unfortunately no humidity measurements were possible. Ascents normally reached 300 mb. and in addition to the temperature data, valuable information was obtained on cloud structure.

The availability of observations both by an aircraft and by a radio-sonde station on the one station over a period of some months made possible a comparison between the two methods. The lack of humidity measurements was a drawback on the aircraft ascent, but the indifferent humidity values obtained by the American radio-sonde gave this instrument little advantage in that respect. The British meteorological unit plotted the two ascents, for approximately the same time, on the one adiabatic diagram. The ascents were often totally dissimilar, and experience suggested that the aircraft was generally much more reliable than the radio sounding.

Aircraft Reconnaissance

Because of the extreme shortage of surface observations over the ocean areas, every attempt was made to provide aircraft reconnaissance as a substitute. Attempts to this end were begun before the British force left the United Kingdom. As an interim measure, the use of one aircraft per day was authorised for meteorological reconnaissance, the track flown to be determined by the Senior Meteorological Officer. Such flights were of great value; the aircrew were somewhat hampered in not having trained meteorological observers on board but their keenness compensated in some measure for this deficiency. The aircrew were trained in observing and a member of the meteorological staff occasionally accompanied the flight.

The coding and transmission of observations to base proved a considerable difficulty. The normal code proved too unwieldy and too comprehensive for use in an aircraft not fitted for meteorological reconnaissance and not carrying meteorological air observers. Other codes designed specially for use by operational aircraft, such as the REOB code, were not comprehensive enough. Finally, a code was devised locally, after consultation with the aircrew, which remained in use until the end of the European war. Messages received in it were transposed into the normal code before re-transmission to other North Atlantic bases.

One of the tasks allotted to No. 269 Squadron was to carry out meteorological reconnaissance from the Azores, for which purpose it was equipped with six Hudson aircraft, on whose arrival meteorological reconnaissance was taken over by this squadron. The Hudsons were later replaced by Warwick aircraft, most of which were fitted with strut psychrometers and aneroid barometers before leaving the United Kingdom. Fortunately, the squadron retained two

Hudsons, for the serviceability of the Warwicks was so low that on many occasions not a single one was available out of the seven held on squadron strength. On these occasions the sortie was made by a Hudson and when both Hudsons were also unserviceable, the sortie was made by an aircraft of one of the operational squadrons.

During most of the period when British aircraft made meteorological reconnaissance flights from the Azores, the time of departure, track and length of flight were at the discretion of the Senior Meteorological Officer, subject to considerations of the aircraft's safety. It was thus ensured that the maximum possible amount of information likely to be of help in forecasting for the Azores would be obtained. Very often the flight lay along a quasi-stationary front in an attempt to discover any incipient waves on the front which might affect the Azores bases, a very common situation in the Azores.

In March 1944, the American Army also established a routine reconnaissance flight at Lagens. The flight, known as 'Eagle', was operated by Mitchell aircraft. There was a choice of four tracks open to the Base Weather Officer. In this connection, the Senior British Meteorological Officer and the American Base Weather Officer normally held an evening conference on the tracks of the British and American flights for the following morning. This arrangement proved very valuable and avoided unnecessary and wasteful duplication of information. The 'Eagle' flight normally flew at 950 mb. on the outward track to 400 miles, made an ascent to 700 mb. and returned to base at 700 mb.

Another meteorological reconnaissance flight was established in September 1944, with Lagens as one of the terminals. This flight was 'Sharon'—a shuttle flight between East Anglia and the Azores with one flight daily in each direction. It was operated by an American squadron based in East Anglia with a detachment in the Azores. The aircraft outward-bound from England set course from St. Eval for point 48° 30′ N., 21° 30′ W., where an ascent was made to 400 mb. with a descent to 500 mb. The aircraft then set course for Lagens at 500 mb. descending to 950 mb. at 44° 45′ N., 23° 50′ W. The aircraft returning to England followed this procedure in reverse. Departure times were arranged so that the top of the ascent on the outward flight would be reached at 0600 G.M.T. and the foot of the descent on the return flight at 1800 G.M.T. The aircraft operated under the control of Nos. 19 and 247 Groups, R.A.F., and carried U.S. meteorological air observers trained by the Meteorological Office. Fortress aircraft were used. This flight was discontinued in the summer of 1945.

The 'Nocturnal' meteorological flight from Gibraltar occasionally landed at the Azores.

Security[1]

As observations from the Azores are of fundamental importance for Atlantic and European forecasting, it was hoped to withhold the reports from all but Allied recipients. Attempts to do this were made before the landing in the Azores and were renewed after the landing. At first, the Portuguese would not agree, as they considered it to be a breach of their neutrality, but they agreed to withhold the reports from everyone including the Allies. This was unacceptable and until 1 September 1944, the Azores observations, except

[1] *See also* Chapter 32.

station Angra and the British stations established, continued to be issued by Horta (CTH) in clear except during the brief period immediately after the arrival of British forces in the islands.

The agreement between Britain and Portugal, made before the arrival of British troops in the islands, stipulated that all communications in and out of the Azores would cease on 6 October 1943, the day before the arrival of the British forces. Unfortunately, the Portuguese interpreted this embargo to include the meteorological transmissions from Horta, which were discontinued for about two weeks. The officer in charge of the British unit made strong representations through the British Commander to have the Horta transmissions restarted, as lack of the Azores observations was proving a severe handicap to the Allies, not least to the British forecasters in the Azores. The matter was finally referred to the British and Portuguese Foreign Offices before the Horta station was reopened, the Portuguese agreeing to in-clear transmissions only.

Discussions continued with a view to using cyphers for all Azores observations, but it was not until August 1944 that the Portuguese agreed to this. For a number of reasons it was desired to use pad cyphers and the Air Ministry offered to supply these, but at first the Portuguese insisted on using their own cyphers which proved to be of very low security. Finally special cyphers were devised as a compromise.

The agreement with the Portuguese provided for the encyphering of each observation at the observing station and its transmission in cypher to the British H.Q. at Lagens, where the reports were decyphered. A collective was then prepared of these observations, plus observations from British stations in the Azores, which were retransmitted in British cypher, certain precautions being taken to ensure the security of the British cypher. The Portuguese transmissions from Horta ceased with the introduction of this arrangement on 1 September 1944 when, to the embarrassment of the Allies, the Portuguese also suppressed the broadcasts from Monsanta of the reports from stations in Portugal, but they were persuaded to restart these broadcasts after about three weeks.

It was later found necessary to modify the Azores agreement. Where the observations from Portuguese stations in the Azores were transmitted only over submarine cable or land-line, they were sent in clear. This applied to all stations except the two on Flores which were sent in cypher by inter-island radio link to Horta, for onward transmission by cable to Lagens, Terceira.

Services for the R.A.F.

Coastal Command : A very important part of the R.A.F. task in the Azores was to help 'close the gap'. With V.L.R. aircraft based in N.W. Africa, United Kingdom, Iceland and Canada, there was still an area of the North Atlantic in which convoys ran great risks from enemy submarines without protection of shore-based aircraft. The establishment of an Allied airfield in the Azores was to help remove this risk through the provision of air cover by heavy land-based aircraft.

When the British forces arrived, the Lagens airfield did not offer facilities for large aircraft, and for the first few days the only aircraft operating from Lagens were F.A.A. Seafires and Walruses which had been flown ashore from the aircraft carrier escorting the troop convoy. These aircraft carried out

short-range sorties from the airfield within 24 hours of the troops landing on the island. No meteorological data of any kind were then available for the preparation of forecasts, and meteorological protection of these sorties was at first rudimentary. The technique of forecasting from local observations only is difficult in areas with which the forecaster concerned is familiar, but in this case the area was completely strange to all the forecasters and there was much relief when radio facilities were provided within a few days, enabling enough meteorological transmissions to be intercepted to draw at least a skeleton map of the North Atlantic.

Meanwhile, the airfield was being prepared to receive heavy aircraft. Plans were made for the arrival of two squadrons of Fortresses (Nos. 206 and 220) direct from England and one squadron of Hudsons (No. 233) from Gibraltar within about ten days of the landings. At that time, the meteorological situation in the Azores area was dominated by a quasi-stationary belt of bad weather (front) lying approximately east and west just south of the islands. At intervals of 24 to 36 hours minor waves moved eastward on this front and the airfield, which was most of the time in north-easterly winds with good visibility and high broken cloud, would become unfit for periods of four or five hours by very bad visibility (often fog) and low clouds of nimbostratus type accompanied by heavy drizzle. With no airfield within a thousand miles, forecasting for the flight of the squadrons in such a situation was a grave responsibility. However, early on the tenth morning after the disembarkation, a forecast of good landing conditions for the afternoon was sent to England and the two squadrons of Fortresses landed some 12 hours later in brilliant sunshine. The Hudson squadron arrived from Gibraltar a few days later.

With heavy aircraft based in the Azores, the hunt for submarines was undertaken with all speed and energy and with almost immediate successes. The area of operations of Coastal Command aircraft covered that part of the North Atlantic in a circle centred at Lagens, radius about 500 miles. The only land inside this circle is the Azores, the nearest Allied base being Gibraltar, over 1,000 miles away. To the north-east lie the British Isles, the nearest air base there being over 1,000 miles from Lagens; to the north-west, Newfoundland some 1,300 miles away; to the west-south-west Bermuda, almost 2,000 miles away. This geographical situation made weather at base all-important, as diversions not only involved great distances, possibly beyond the aircraft's endurance, but also meant the loss of the aircraft concerned for some days until it could return to base.

The anti-submarine work of Coastal Command continued in the Azores until the end of the war in Europe.

R.A.F. Transport Command : The Azores is an important staging post for transatlantic flying, particularly in the case of flights between North America and North Africa. In addition, when direct crossing between Canada and the United Kingdom or vice versa was made impossible by bad weather, alternative routes via Iceland or the Azores are considered. The Azores thus came in for its full share of transatlantic flying, resembling the centre of a wheel with spokes radiating to Bermuda, Montreal, Gander, Prestwick, South-West England, Gibraltar and North-West Africa. All these routes were flown regularly by aircraft of Transport Command and there were also occasional flights direct to Iceland and to Bathurst. The multiplicity of routes placed a heavy burden on the meteorological office which, for much of the time, was seriously understaffed.

The establishment of a separate forecasting office in the Transport Command section of the airfield was considered, but as this would have caused considerable duplication of work, requiring extra staff, a compromise was adopted. When Transport Command aircraft were making only a short stop at the airfield, the meteorological briefing was given in the Transport Command briefing room, the forecaster going there from the meteorological office, which was located in the Coastal Command Section, about 400 yards away.

At first, the British meteorological office provided for aircraft of all nationalities, but a U.S.A.A.F. Weather Office which was gradually set up on the airfield, took over forecasting for American Army and Navy transport aircraft. Portuguese aircraft made a few flights to and from Portugal. As the Portuguese meteorological staff in Lisbon and in the Azores had no experience in forecasting for these flights, the work was undertaken by the British Offices in the Embassy at Lisbon and in the Azores. Communications and cyphers caused the main difficulties.

Co-operation with Allied Meteorological Services

Two Portuguese meteorological services operated in the Azores: the Meteorological Service of the Azores had headquarters at Angra do Heroismo and observing stations at Ponta Delgada, Angra do Heroismo, Horta and Santa Cruz; the other service, operated by the Portuguese Navy, had headquarters and observing station at Horta and an observing station at Lagens, Flores. Contact with the first of these meteorological services was made on the day of landing, when the officer in charge of the British Meteorological Unit visited the Director at the observatory in Angra. The Director offered all possible help to the British personnel and close liaison was maintained with him and his staff throughout the stay in the Azores with mutual trust and help. Contact with the meteorological service of the Portuguese Navy was not made until the summer of 1944 due to its being located on other islands, the difficulty of inter-island travel and an initial embargo on visits of British personnel to Fayal. However, in September 1944, the Head of the Portuguese Naval Meteorological Service in the Azores visited Lagens to discuss matters of common interest, and a return visit was made by the Head of the British Unit to Horta in March 1945.

The first American units to arrive in the Azores were accompanied by a Weather unit which landed on 7 December 1943 and was accommodated in the room next to that of the British unit. The Americans at first had no facilities for receiving synoptic data and carbon copies of all decyphered reports were made available by the British. With the arrival of American wireless equipment there was a period of much duplication in receiving and decyphering synoptic data, but ultimately the two officers-in-charge arranged for a fair division of this work, with consequent saving in personnel and equipment. The U.S. Weather Office moved from the British office when an American H.Q. was set up in another part of the airfield, and this raised some difficulty in the exchange of synoptic data. The setting up of a teleprinter link was authorised, but there was considerable delay in installing it; in the meantime a system of runners was used, the American and British offices sharing the work. At first the British office handled all forecasting for transatlantic flights of any nationality, but after several weeks, the Americans began to forecast for American aircraft passing through the Azores. From the summer of 1944, a

squadron of the U.S. Navy was based at Lagens, operating under the control of H.Q. No. 247 Group, R.A.F. To this squadron was attached a Weather Unit of the U.S. Navy which, by agreement between the A.O.C. No. 247 Group and the Officer Commanding, U.S. Naval Squadron, was placed under the direction of the Senior Meteorological Officer, No. 247 Group. There was complete co-ordination in the plotting and analysis of charts and in the forecasts issues for U.S. Naval aircraft engaged in joint Anglo-American anti-submarine patrols.

For some time before British forces arrived in the Azores, Pan-American Airways had been operating a Flying Boat service from the United States through the Azores to Lisbon, and had set up a small meteorological unit at Fayal, the Clippers' port of call. The only observations made by the Pan-American office were of sea and swell in the landing area or in Picco Channel plus an occasional radio-sonde ascent. The main duty of the office was to prepare forecasts for the Clipper service. Under an agreement between Pan-American Airways and the Portuguese Government, the Pan-American meteorological office operated in conjunction with the Portuguese meteorological office at Horta, and all synoptic information available to the one had to be made available to the other. The imposition of security measures in the N. Atlantic on the outbreak of war made it necessary to deprive Pan-American Airways in the Azores of all synoptic data, except that which originated in a neutral country, in order not to compromise the cyphers used by the Allies and to avoid any leakage through Portuguese channels. Thus, by 1943, forecasts needed by Clippers calling at Horta were compiled at New York and signalled to Horta, where the Pan-American meteorologists carried out the briefing. First contact with the Pan-American office was made in November 1943 when the Pan-American forecasters asked that the N. Atlantic analysis prepared by the British meteorological office at Lagens should be made available to the Pan-American office at Horta. In view of the known mutual exchange of information between the Americans and Portuguese at Horta, this request had to be refused. The first personal contact between the British and Pan-American meteorologists was made in March 1945.

Technical Problems

Before their arrival in the Azores, the British forecasters' views of the weather there were coloured by the idea of a semi-permanent Azores anti-cyclone and were based on M.O.446b(1) 'Weather in the Atlantic from the Azores to the African Coast.' This was the only publication in English containing any discussion on weather in the Azores region. It was soon discovered that the phrase 'Azores anti-cyclone' is misleading as the mean axis of the sub-tropical anti-cyclone actually lies approximately along the 35th parallel, almost 300 miles south of the Azores. The effect of this is to place the Azores in the area of predominating south-west to west-south-west winds and to make conditions very favourable for trailing fronts in the region of the islands. These trailing fronts are normally linked with the depressions which affect Britain and Western Europe.

One of the main difficulties in forecasting for the Azores bases was in timing the movement of such trailing fronts which sometimes move at only a few knots; if they are very near the islands, forecasting of airfield conditions is difficult. Often, the fronts are sharply defined and by no means inactive, with cloud

base on the surface or at a few hundred feet and accompanying heavy drizzle. With a slow speed of movement clearance over the airfields could be very slow even although the fronts might be comparatively narrow. Two additional factors which made successful forecasting in such a situation still more difficult were that the mountainous nature of the islands produced startling orographic effects and that frequent minor waves moved eastward along the quasi-stationary front.

With the shortage of synoptic observations, the study of the movement of the trailing fronts depended almost entirely on good and regular aircraft reconnaissance. It was discovered early that the barometric tendency could not be taken at face value in considering the movement and development of these fronts. In latitude 40° N. the diurnal variation of pressure becomes significant but pressure changes due to frontal activity alone may be quite small and may be easily masked by the diurnal variation, which has a winter amplitude of about 1·8 mb. It was found necessary, therefore, to construct tables giving the diurnal variation of pressure for each month of the year expressed as the tendency which would be reported at the synoptic hours if no other pressure changes were taking place. These tables were based at first on 20-year average pressures for Angra do Heroismo obtained from the Portuguese Meteorological Service in the Azores. The tables proved of very great value in sorting out diurnal changes and changes due to development.

A factor which detracted from the value of previous literature on Azores weather, and caused misconceptions, was that the long established Portuguese stations in the islands all had similar exposures. They were all on the east, south-east or south coasts of the islands and all sheltered from north to west by considerable mountain masses, so that any climatological statistics obtained from observations made at these stations must relate only to those parts of the islands which have similar exposures and cannot be accepted as applying to parts which are on the other side of the mountain ranges. For example, weather at Lagens airfield was often found to be very different from that at Angra do Heroismo for, although both are on the same island and are only 10 miles apart, they are separated by a mountain range, the lowest part of which is 1,000 feet high. The highest point in the island, which is only some 60 miles in circumference, reaches 3,500 feet. Even when aircraft reconnaissance gave a comprehensive and accurate picture of the weather over the ocean, considerable allowance for orographic effects had to be made in forecasting for the airfield at Lagens.

A type of weather which caused some difficulty to the forecasters in the Azores was that associated with high pressure to the north of the islands, in which case the airfield was under the influence of north-easterly winds. Generally, there were no well marked fronts associated with this type of weather. However, the surface air had often been modified in two ways during its passage round the anti-cyclone; firstly, during its northward and north-eastward movement, west of the anti-cyclone, it had been in contact with progressively cooler water and this cooling, combined with subsidence aloft, produced a marked inversion, usually at a height of about 3,000 feet, with high humidity below the inversion; secondly, as the air turned southwards towards the Azores, it came into contact with progressively warmer water, which gave rise to convection in the lower layers beneath the inversion. Marked bumpiness at low levels was reported by aircrew in such a situation and precipitation was

often met over the ocean and also on the exposed coasts of the islands. The precipitation can best be described as 'drizzle showers', of irregular occurrence and varying duration. Convection was rarely deep enough to give even moderate showers except in a few cases when the effect of orography was enough to break down the inversion locally near the islands. Timing the onset and clearance of these showers was very difficult, and the forecaster's problem was enhanced by the fact that the accompanying cloud base and visibility conditions were such as to render the airfield completely unserviceable.

When there was high pressure sufficiently far north of the Azores, there was always the chance that the islands might be affected by low pressure systems to the south. Synoptic data were scarce enough in any direction, but to the south and south-west there was none at all, except such information as could be gathered by reconnaissance flights. Unfortunately, developments to the south were sometimes very rapid and as nothing was known of the characteristics of the southern air masses, forecasting these rapid developments was no easy matter. Occasionally, storms of hurricane intensity developed to the south and severe damage was caused to airfield installations. In most cases, the structure of these depressions was obscure and the fronts associated with them often had to pass the islands before their existence was known.

Bermuda

The Meteorological Service of Bermuda was set up in 1932 as a Colonial Government service, primarily to supply meteorological information to the Fleet on the America and West Indies station. The office was at St. Georges. In 1936, the increasing importance of Bermuda as a staging post on air routes made it necessary to augment the Bermuda Meteorological Service by the addition of staff and radio equipment, the cost of which was borne by the Air Ministry. The staff was further augmented in January 1941 by the attachment of a forecaster from the United Kingdom.

In view of the projected use of Bermuda for the delivery of Catalina aircraft to the United Kingdom, the meteorological office was moved in August 1941 to Belmont Manor Cottage, a site nearer to Darrell's Island, the flying boat base. Manor Cottage later became the operations building of the Ferry (later Transport) Command unit and housed operations, signals and meteorological staff.

On 1 October 1941, Air Ministry took over full financial responsibility for the meteorological service in Bermuda and complete administrative responsibility on 1 July 1942.

As the U.S.A.A.F. had established an airfield known as Kindley Field, near St. George, which was used increasingly by aircraft of Transport Command, it became necessary to review, towards the end of 1943, the provision of British meteorological briefing facilities.[1] It was decided to transfer the main forecasting centre to Kindley Field, and to set up a subsidiary forecasting centre at Darrell's Island; these moves took place in August and October 1944 respectively; the reporting station had already been transferred to Darrell's Island on 1 September 1944. The administrative centre of the meteorological service remained at Belmont.

[1] A.M. File S.77458.

The pre-war establishment included the Superintendent, one Assistant Meteorologist (deputy to the Superintendent) and two forecasters, plus seven clerical staff (assistants recruited locally) and two W/T operators. Early in 1942, Air Ministry agreed to a revised establishment consisting of the Superintendent and Deputy, four forecasters and 13 assistants; officer posts were to be held by civilians, but airmen meteorologists could be held against the assistant posts; some local assistants who volunteered to join the R.A.F.V.R. and were above the age of 18 and medically fit, were enlisted. The staff taken over by the Air Ministry in 1942 included five officers and eight airmen meteorologists. Later in 1943, all the officer staff, except the Superintendent, were militarised; the staff was increased as requirements grew and by September 1944, it included eight officers and 34 airmen besides the Superintendent. These provided the staff for the Headquarters at Belmont, the main forecasting centre at Kindley Field and the subsidiary centre at Darrell's Island. Although the administrative H.Q. was 1½ miles by water from Darrell's Island and some eight miles from Kindley Field, the disadvantages of its being separated from the forecasting centres were offset by a great improvement in the briefing facilities which the establishment of separate offices at Kindley Field and Darrell's Island permitted.

At first the two W/T operators of the Bermuda Meteorological Service collected enough data from the W/T broadcasts of the American meteorological station at Arlington. These broadcasts were 'in clear' until the United States entered the war on 8 December 1941. Also, synoptic data for the Azores, Spain and Portugal were available from the national broadcasts of those countries. Reports from Canada, the United Kingdom and Barbados were received by cable. W/T point-to-point channels later developed considerably consequent upon the development of activities of Ferry (later Transport) Command, and a large radio-communications centre was set up at Flatts, about half-way between Belmont and Kindley Field. From Flatts, data could be distributed by teleprinter to any of the meteorological centres and could be exchanged between the centres as required. By mid-1942, synoptic information was being received from New York, Dorval, Jamaica, Barbados and Prestwick, and by mid-1944 from Nassau and Trinidad. By then, the number of air routes being served had increased, and advisory forecasts were being received from Dorval, Prestwick, Rabat Sale, Lagens and Nassau. Radio-sonde data were provided by the Aerological Office at the U.S. Naval Base at Kings Point. Also, from December 1944, the Americans operated meteorological reconnaissance flights from Kindley Field.

At first, apart from information supplied to the R.N. Signal Station for broadcast to H.M. ships, there was little distribution of data outside Bermuda. Local reports were cabled to the United Kingdom and Canada. By mid-1942, routine reports were being supplied to Dorval, Washington, Jamaica and Prestwick and to H.M. ships; this part of the work had developed into a considerable schedule of W/T distribution by May 1945. Besides flight and landing forecasts, gale and hurricane warnings were issued as necessary; local forecasts were distributed to various addresses twice daily.[1]

The original function of the Bermuda Meteorological Service was to provide data for the Fleet, but towards the end of the war, the work became predominantly forecasting for aviation. For the first two months after the Air

[1] A.M. File S.104288.

Ministry took over, some 70 flight forecasts per month were issued. This was exceeded in 1943 and a peak period was reached in the first five months of 1944 when some 280 flight forecasts per month were issued. The main flights being covered were :—

- Reinforcement flights from Dorval, Gander or Elizabeth City via Kindley Field to the Azores.
- Twice-weekly shuttle service operated by No. 45 Group to and from Dorval via Elizabeth City.
- Special flights by aircraft of No. 45 Group to Trinidad, Jamaica, Nassau or other points in the West Indies.
- Civil flights (B.O.A.C.) between Baltimore, Lisbon and Foynes.
- Civil flights (Pan-American and American Export Airlines) between New York (La Guardia), Lisbon and Foynes.

Towards the end of the war, the average of flight forecasts issued per month fell to less than 200, and for the last few months of the war was under 100.

West Indies

In the early part of the war, it was uncertain where, by whose authority (Air Ministry or Admiralty) and to what extent, additions should be made to the existing rudimentary meteorological organisation. Most of the British Colonial units were maintaining climatological stations but, except in Jamaica, these were run by part-time observers. There was no co-ordination of meteorological work other than that arising from the hurricane warning service of the U.S. Weather Bureau, to which the local meteorological stations contributed telegraphic reports during the hurricane seasons. The Pan-American Airways Company maintained a forecasting service for its own needs.

In view of the discontinuity of the Meteorological Office units in the West Indies, the history of these units is set out separately in the following paragraphs.

Jamaica

On his arrival from the United Kingdom in July 1940, the Meteorological Officer made contact with the Naval authorities and the Jamaica meteorological Service. The latter was a small organisation concerned mainly with the climatological work of the island, but it also distributed hurricane warnings provided by the warning service of the U.S. Weather Bureau and made pilot-balloon observations, in which the British Meteorological Office later co-operated, a number of double-theodolite ascents being made. The main office was at first in Kingston, but was transferred in December 1940 to the Royal Naval Air Station on 'the Palisadoes,' a narrow strip of land on the other side of Kingston Harbour from the town.

In January 1941, it became known that ferry aircraft were flying via Bermuda and would not be using the route Jamaica—Trinidad—Bathurst, and it was learned in June 1941 that R.A.F. staging-post facilities were unlikely to be needed in Jamaica. The meteorological office staff was then reduced to one officer who carried on alone until the work was taken over in February 1942 by the Naval Meteorological Service when they became responsible for meteorological services in Jamaica.

Control of the meteorological services in Jamaica reverted to the Meteorological Office in November 1943. An officer had been chosen to take charge and he was posted to Jamaica in October 1943. He took over from the R.N. meteorological officer on 13 November.[1] Two local assistants were recruited and trained during November and December, during which period naval ratings continued to perform assistant duties, and by May 1944, the staff included five local assistants.

The R.N. Air Station, Palisadoes, closed down in November 1944, and the Admiralty transferred the airfield to the Jamaica Government in December.

As it had been agreed that the work of the former Jamaica Government Meteorological Service should be taken over by the Meteorological Office, the meteorological office in the Public Works Department, Kingston, was closed and records, instruments and equipment were transferred to Palisadoes on 1 January 1945.

Liaison was maintained with the U.S.A.A.F. Weather Section at Vernam Field, the American-controlled airfield.

An assistant was sent to Belize (British Honduras) in February 1945 to set up a reporting station, the installation of R.A.F. point-to-point W/T channels having made communications available with Trinidad, Nassau and Jamaica. Observations were made by staff of British West Indian Airways in Belize and transmitted as required in connection with scheduled air services.

W/T broadcasts of the meteorological data required for forecasting were intercepted at first by Cable & Wireless Ltd., but after the move to Palisadoes in December 1940, R.A.F. W/T operators undertook reception. In October 1940, it was arranged for reports to be telephoned thrice daily from the lighthouses at Negril Point and Morant Point, at the extreme western and eastern points, respectively of the island.

Instruction in making weather observations was given in May 1941 to a W/T operator (Government service) from Cayman, a dependency of Jamaica, so that he could provide reports from there.

Synoptic charts were plotted from September 1940; local forecasts were supplied regularly and occasional route forecasts were supplied for aircraft. After a lapse, when the meteorological services in Jamaica were provided by the Naval Meteorological Service, the Meteorological Office resumed the plotting of synoptic charts in December 1943. Upper air charts were prepared from June 1945 onwards.

Until 31 August 1944, the hours of observation were 00, 06, 12, 1800 G.M.T. and from 1 September 1944 to 31 July 1945 were 0030, 0630, 1230, 1830 G.M.T. in accordance with the standard practice in the Caribbean area.

Synoptic information was obtained mainly through interception, by R.A.F. W/T personnel, of U.S. collective broadcasts, at first from Arlington and Balboa but later, from May 1945, from New Orleans. Synoptic information was received from Bermuda by point-to-point W/T and the Fleet Synoptic message by cable. Information was exchanged with the U.S.A.A.F. at Vernam Field, and from May 1945 the staff of Pan-American Airways supplied copies of the Pan-American Airways hourly collective broadcast from Port au Prince, Haiti. Local synoptic information was passed by R.A.F. point-to-point W/T to Bermuda, Dorval and Trinidad.

[1] A.M. File S.69269.

A large distribution of local forecasts was maintained to Service and Civil authorities and the local Press. Forecasts for shipping, storm warnings and bulletins were issued as required. Climatological information was also supplied and rainfall data were published.

The needs of aviation were not large, amounting to, at most, 65 route forecasts per month. The main recipients of these forecasts were R.A.F. aircraft operating to Jamaica, B.W.I.A., K.L.M. and P.A.A. Routes covered included those to Belize and Miami, Trinidad, Curacao, Nassau, Haiti and other West Indian islands.

Forecast exchange with Trinidad was begun after the opening of the Meteorological Office station there in 1945.

Barbados

A meteorological assistant went to Barbados in July 1940 to select possible sites for a meteorological office before the forecaster arrived in September. There were then no regular units of the R.N., Army or R.A.F. stationed in Barbados. An office was opened in the Garrison buildings and the services of W/T operators of the Signallers Section, Barbados Volunteer Corps, were used.

The forecaster was withdrawn to Bermuda in January 1941 and the assistant remained in charge until September 1942; afterwards the work was carried on by two local observers who had been recruited early in 1941 and took to duty in February of that year. The office was transferred to Seawell aerodrome (a few miles S.E. of Bridgetown) on 16 February 1942; instruments were quickly erected and observations started there on the 23rd. The senior observer was transferred temporarily to Grenada in July 1945 to assist in opening a new station there.

In the early part of the period, synoptic charts were prepared from data received by collective broadcasts from Arlington. Local forecasts were issued. Later, only climatological data or weather reports were issued locally as required. Synoptic reports were passed by cable daily to Bermuda from November 1942 to July 1945 for re-broadcast in the Fleet Synoptic messages. From August 1945, synoptic reports were passed by W/T thrice daily to R.A.F.T.C., Trinidad, via B.W.I.A.

Trinidad

Possible routes for the delivery of aircraft from the U.S. eastwards had been discussed and, in 1940, the routes Barbados—Bathurst and Georgetown—Bathurst or Freetown were being considered. As it appeared that Georgetown would not be suitable as a point of departure, it was decided to transfer all facilities to Port of Spain, Trinidad. Air Ministry responsibility there had already been defined as that of co-ordination with the existing organisation. A commissioned meteorological officer was, therefore, posted to Trinidad where he arrived in January 1941. The situation in Trinidad was then as follows:—

(*a*) A small Naval meteorological unit was awaiting the arrival of equipment to open an office at Piarco aerodrome, 18 miles east of Cocorite, the flying boat base of Port of Spain.

(*b*) A forecasting office of P.A.A. was operating at Cocorite but it was expected that after some months P.A.A. would transfer their office to Piarco.

(*c*) Adequate signals staff of the R.A.F. Flying Boat Control Unit were available to intercept W/T broadcasts.

The Air Ministry meteorological officer worked in collaboration with the Naval meteorological unit and gave lectures for the Trinidad Air Training Scheme. No developments occurred in connection with the southern aircraft-delivery route and in April 1941 the officer reported that Trinidad was to remain merely a reserve base for transatlantic ferrying of aircraft.

Arrangements were made early in 1941 to deliver Catalina aircraft from the U.S.A. to the United Kingdom via Bermuda instead of via Jamaica, Trinidad and West Africa. The need for a meteorological organisation for the latter route therefore lapsed temporarily and the forecaster was withdrawn from Trinidad in July 1941.[1] Later in the year, the route via Trinidad—Belem—Natal—Accra for transatlantic delivery flights assumed a new importance and the extent to which meteorological requirements could be covered by P.A.A. and R.N.A.S., Piarco, was discussed.

Following a decision early in 1943 that aircraft from the U.S. for the R.A.F. would be ferried on a southern route via Piarco, the British Meteorological Liaison Officer in Canada was sent via Washington and Nassau, where meteorological organisation for the route was discussed, to act as Meteorological Liaison Officer with the U.S.A.A.F. Weather Office at Waller Field, about nine miles from Piarco, where the Americans had an airfield. He arrived in Trinidad on 30 March 1943 and reported the situation as follows :—

(*a*) Flight forecasts and briefing were being provided by the meteorological office of P.A.A. at Piarco.

(*b*) At Waller Field, where a U.S.A.A.C. Base was situated, there were two Weather Offices, the U.S.A.A.C. Base Weather Office and the U.S.A.T.C. Weather Office, on opposite sides of the airfield. It was expected that these would soon be combined and provide 24-hour forecasting service.

(*c*) At Piarco, also was the R.N. meteorological unit whose functions were entirely instructional.

The British Meteorological Liaison Officer had discussions with the various authorities and made recommendations regarding the meteorological organisation required in Trinidad ; he also maintained a watching brief over the meteorological arrangements then available to Transport Command crews passing through Trinidad ; he accompanied the Inspection Party of A.O.C. No. 45 Group to Belem, Natal, Ascension Island, Accra and Atkinson Field (British Guiana) and returned to Dorval at the end of June 1943.

Following the visit of the Meteorological Liaison Officer to Trinidad, it was proposed later in 1943 that a British forecaster should be attached to Waller Field and travel between the meteorological station there and Piarco, where British aircraft would be briefed, but lack of transport facilities made this scheme impracticable. Complaints were made during 1944 about the inadequacy of meteorological facilities in Trinidad by the civil air lines, B.O.A.C. and B.W.I.A. and by the A.O.C.-in-C., Transport Command. The latter pointed out in October 1944 that, besides other transport services, his command was operating about 100 delivery aircraft per month from Nassau via Trinidad and the North Brazilian coast to West Africa and that no meteorological facilities were provided at Trinidad other than the issue of forecasts ' which are purchased from the Pan-American Airways office at Piarco '.[2]

[1] A.M. Files S.64938/I and S.77857/I. [2] A.M. File S.77857.

Meanwhile, as a part of a scheme for a unified colonial meteorological service, proposals for a West Indian Meteorological Service had been prepared and were under consideration, but in view of the delay which would occur in implementing such a plan, it was agreed to proceed with the establishment of a Type 1 meteorological office at Trinidad. A Senior Meteorological Officer arrived in Trinidad on 5 January 1945 and a forecasting officer arrived on the 24th. No office was available at Piarco, but work started at the end of January and the office was occupied in March. Meanwhile, four airmen meteorologists had arrived and a 24-hour service was begun on 23 March 1945. In May, hourly observations were started and the forecasting work for the R.A.F. was taken over from the meteorological office at P.A.A. ; forecasting for B.W.I.A. was taken over in August.

A teletype, installed by U.S. Army Signals in March 1945, gave connection with the Trinidad meteorological circuit and thereby provided a good coverage of synoptic data for the Caribbean and South America, enabling four charts to be plotted daily.

The Fleet collective message from Bermuda and data from Jamaica and Nassau and, later, from the Azores, were received by W/T.

Exchange of forecasts with Nassau started in June, and of synoptic data with Yundum (West Africa) in August 1945. Weather reports were supplied to the control section regularly and synoptic data to Nassau and Jamaica. Forecasts were supplied to the R.A.F. and to B.W.I.A. By the end of the war some 50 to 60 route forecasts per month were being issued.

Nassau (Bahamas)

At about the time that interest in the southern route for delivery for aircraft from the U.S. renewed, a commissioned meteorological officer was already on the way to Nassau to set up a meteorological station for the requirements of No. 111 O.T.U. He reached Nassau on 6 February 1943 and two assistants who had arrived on 4 February were commissioned as forecasters from that date. An office was opened at the R.A.F. station. Three airmen assistants arrived in May and a full 24-hour forecasting and observing service was introduced on 3 June 1943. Later in 1943, local assistants were employed.

In January 1944, the main airfield was named Oakes Field and a satellite airfield about eight miles away was named Windsor Field. The O.T.U. H.Q. and the Operations Room were situated at the former and the R.A.F. H.Q. at the latter. A small subsidiary meteorological office was opened at Windsor Field on 19 July 1945.

The U.S. Weather Bureau proposed early in 1945 to install automatic weather stations at two isolated sites, Dog Rocks and Orange Cay, in the Straits of Florida and under the jurisdiction of the Bahamian Government. Agreement was reached between the various Governments and the U.S. authorities provided the installation in May 1945. The meteorological officer from Nassau accompanied the U.S. party in a U.S. Coastguard Ship and reported on the installation to the Meteorological Office.[1]

[1] A.M. File S.99852.

At first W/T broadcasts of data from Balboa and New Orleans were intercepted by R.A.F. W/T operators, but from June 1943, the main source of synoptic data was the American meteorological W/T station, known as 'Tropical Radio,' at Hialeah, Florida, which maintained a point-to-point working with Nassau Telecommunications. Thence, data were passed by teletype. Hurricane advisory forecasts and warnings were received in the same way from the Miami office of the U.S. Weather Bureau. Information was also received by point-to-point W/T from Dorval and Bermuda; the U.S.A.T.C. channels provided information from Miami and Morrison Field, Florida. Later, in 1945, exchange of forecasts with Trinidad was arranged and at about the end of the period, arrangements were in hand to install W/T channels in the meteorological office itself, which had moved into new quarters at Oakes Field in August, so that W/T reception could be carried on direct from Dorval and Trinidad, enabling the use of 'Tropical Radio' to be discontinued.

Much of the work was concerned with instruction to pupils of No. 111 O.T.U. Local forecasts were supplied to the two airfields and flight forecasts were provided in connection with operational training, as well as for communication, transport and civil flights. Forecasts were exchanged with meteorological units at Dorval, Bermuda and, later, Trinidad. Hurricane warnings were distributed as necessary. On two occasions, 15 and 31 July 1944, special reconnaissance flights were sent out to track a tropical disturbance.

Flights of Ferry, later Transport, Command to Trinidad or Borinquen, Puerto Rico, started in March 1943. At first, the route forecasts were obtained from P.A.A., Miami, and later, until the British meteorological office was fully working (June 1943) from La Guardia, New York, via Dorval.

The activities of the office are shown by the fact that for short range flights and training flights from January 1944 to June 1945, about 150 forecasts were issued per month; the figure fell to 86 by July 1945 and to 32 by August 1945. For long flights of R.A.F. Transport Command, an average of 130 route forecasts were issued per month from April 1943 to June 1944 and thereafter at an average of 55 per month.

Grenada

The question of setting up a weather reporting station in Grenada was raised at the end of 1944 by the U.S.A.A.F. through the U.S. Weather Bureau and the British Meteorological Liaison Officer in Washington. By that time, plans for setting up a unified meteorological organisation in the West Indies, which were being considered in the United Kingdom, included a reporting station in Grenada. In view of the factors involved, and with a view to assisting the forecasting at Trinidad, it was decided that the Senior Meteorological Officer should visit Grenada to investigate and report on the question of recruiting and training two local observers. The Senior Meteorological Officer duly made his report on 20 February 1945.

Early attempts to recruit local observers were unsuccessful and the Senior Observer at Barbados was, therefore, transferred to Grenada and, under the supervision of the Senior Meteorological Officer, Trinidad, he set up an observing station early in August 1945. The observer made observations at Pearls Airfield, hourly as far as possible, between 0800 and 1700 zone time from

18 August 1945. The reports were sent to Trinidad on W/T channels of B.W.I.A., and thence to Nassau, Jamaica, Bermuda and Undum. Assistance was given by the Operations Officer of B.W.I.A. who undertook to make observations during the absence of the observer.

* * * * *

The war-time history of the meteorological service in the West Indies showed that its numerous Governments, independent of one another, made an effective meteorological organisation impossible without some central co-ordinating authority.

PART IV

TECHNICAL ASPECTS OF THE SYNOPTIC SERVICE

CHAPTER 27

SOURCES OF METEOROLOGICAL INFORMATION

Observing Stations in the United Kingdom[1]

Shortly before the outbreak of war, there were, in the United Kingdom 49 principal meteorological observing stations and 63 auxiliary stations to which, in accordance with the International System of Index Numbers, were allocated principal index numbers between 107 and 168 and auxiliary index numbers between 220 and 442 respectively.[2] The term 'Observing Stations' in this section is interpreted as meaning stations making weather observations in a manner prescribed by the International Meteorological Organisation, the observations being made available regularly to, and for dissemination by, the Central Forecasting Office and including information of direct use in the construction of synoptic charts. This interpretation excluded observing stations such as those maintained by private individuals and corporations making observations of rainfall only, private observers and schools which made monthly returns to the Climatological Branch of the Meteorological Office, and places concerned solely with making observations for special purposes, *e.g.*, Agricultural Colleges and Health Resorts, except in so far as such stations were recruited during the war to make and supply reports which could be used for charting purposes or for giving assistance in meeting aviation requirements. Some such stations were incorporated in the Royal Observer Corps network of stations and supplied weather reports under the 'Obcor' scheme.

Until the outbreak of war, abbreviated plain language reports from many stations were being broadcast by the Air Ministry Meteorological Radio Station at Borough Hill at hourly intervals during the day, or in some cases at selected hours, for the benefit of aviation. This radiotelephony broadcast ceased on the outbreak of war.

In May 1939, the question was considered from which health resorts, if any, it would be desirable to have observations in war-time, from the point of view of their value as potential auxiliary observing stations reporting as often as seemed desirable. This led to a more general discussion on observing stations in the United Kingdom from which reports were desirable to fill up blank areas on the weather maps, and it was thought that a considerable number of new observing stations, mostly in Scotland and Ireland, might have to be opened.[3] The following sites were considered :—

Locality	*Suggested Sites*
North Devon	Simonsbath.
West Wales	Aberystwyth, Highground of Carmarthen.

[1] S.I. 117.

[2] *See* Appendix 18 for a map showing the distribution of the principal reporting stations in the British Isles in March 1939.

[3] A.M. File S.53679.

Locality	*Suggested Sites*
Gloucester, Worcester, Shropshire ..	Malvern, Ludlow.
Cumberland Coast	St. Bees Head or Millon.
North-West Scotland	Oban, Boisdale, Skye, Rudh Re, Cape Wrath.

Kyle of Lochalsh, Fort William and Shrewsbury were also suggested.

Other activities during the first few months of war made it impossible to establish and equip new observing stations, but during the years 1940–44, the number of such stations steadily increased owing to the opening of airfields required for operational purposes; reports at many airfields were provided by U.S.A.A.F. personnel. The rate of increase of observing stations was roughly the same as that in the number of recipients of the first channel teleprinter broadcast from ETA.[1]

Meteorological Reporting Ships

A supply of meteorological reports from the Atlantic was assured in peace-time by the voluntary work of Masters and Officers of the Voluntary Observing Fleet organised by the Marine Branch of the Meteorological Office. The reports were mainly confined to the principal steamship routes but were extremely valuable as they provided data from areas which would otherwise have been a blank on the meteorological chart.

The imposition of W/T silence on British Merchant Ships on the outbreak of war resulted in a serious lack of meteorological reports from the Atlantic, especially the Eastern Atlantic where the British Observing Fleet had provided almost all the available information. The only ship specially chartered for meteorological reporting in the Atlantic, the French *Carimaré*, was also withdrawn from service.

The need to adopt special measures to secure at least a minimum of information from the Atlantic area had been realised. The possibility of using meteorological flights to such an extent as occurred later in the war may have been envisaged but the acute shortage of aircraft and aircrew made such an organisation impracticable at that time. As efforts to persuade the Admiralty to permit a certain number of reports from ships in war-time failed, a joint Anglo-French meeting, held at the Office Nationale Meteorologique on 4 October 1939, recommended investigating the possibility of using fast armed trawlers or submarines to provide weather reports from the Atlantic area.[2]

The Marine Branch of the Meteorological Office submitted the first concrete proposals in October 1939. These were, briefly:—

(*a*) That two trawlers of the large Arctic or Bear Island type be bought or chartered. One of these would be on patrol in the area selected while the other would be on ' standby '.

(*b*) That the ships be offensively armed. This was considered of the first importance and vital to the whole scheme.

(*c*) The observation area would be bounded by latitude 45° and 55° N. and longitudes 15° and 35° W. The trawler would patrol at full speed in this area in order to minimise the risk of interference by enemy craft and would send W/T reports to the Admiralty at agreed intervals.

[1] *See* Appendix 19 for a map showing the distribution of the principal reporting stations in the British Isles in April 1944.

[2] A.M. File S.58250.

(*d*) Each trawler would spend 19 days at sea and nine days in port, allowing five days on passage to and from the observing area and 14 days patrol within the area.

The D.M.O. sought the reaction of the Admiralty to these proposals and to the French proposal to use submarines on 14 October 1939. The reply said that the proposals were not then considered justifiable and stressed the advantage of securing reports from aircraft as an alternative. This aspect had been exhaustively considered by the Meteorological Office and D.M.O. pointed out to the Director of the Naval Meteorological Service (D.N.M.S.) that although simple meteorological observations from operational aircraft were obtained, they were from areas relatively close to land, and regular reports from a meteorological ship were still regarded as essential. It was not then considered practicable to use aircraft solely for making meteorological observations.

The Air Council suggested to the Admiralty on 4 March 1940 that the *Discovery II* and the *William Scoresby* be allotted for meteorological reporting duties. The D.M.O. gave as additional arguments, the opening up of the N. Atlantic flying route and the need to forestall the Establishment of American reporting ships on this route, entailing the availability of reports to the enemy. The Admiralty replied that the *Discovery II* and the *William Scoresby* were not available for the proposed duties, but recognised in principle the desirability of providing such craft and agreed to review the position later. The Air Council again referred this question to the Admiralty on 12 July 1940 and direct planning began on 22 July at a meeting attended by the Directors of the Meteorological Office and the Naval Meteorological Service. The main decisions were:—[1]

(*a*) *Type of Ship.*—It was agreed that the ships should, if possible, conform to the following specifications:—

Speed—Minimum 10 knots.

Range—Minimum 3,000 miles.

W/T Equipment—Short wave if possible; power to permit reception at both United Kingdom and Botwood.

Armament—4-in. or 12-pdr. HA/LA gun; two Hotchkiss ·303 machine guns, Asdic and depth charges.

(*b*) *Personnel.*—D.M.O. recommended that the ships be captained by volunteer R.N.R. officers of the Marine Branch. He stressed the importance of placing a highly qualified and experienced Scientific Officer in each ship and undertook to provide such officers. D.N.M.S. proposed to place one of his R.N.V.R. meteorological officers on each ship.

(*c*) *Patrol Area.*—D.N.M.S. explained that the Admiralty would need three ships to avoid the routes traversed by convoys. It was agreed in principle that a number of alternative patrol routes should be specified and that instructions should be sent to the ships as necessary to indicate the route which they were to follow. It was also agreed that the Meteorological Office and the Naval Meteorological Branch should submit their needs in this connection to the Admiralty for transmission to the ships through the C.-in-C. of the port from which they sailed.

[1] A.M. File S.58250.

(*d*) *Reports Required*.—D.N.M.S. urged that reports from the ships be made at first only at 0100, 0700, 1300 and 1800 hours. He undertook to discover from the Admiralty Signals Branch whether it was desirable from the point of view of the ships' safety, to vary the times of transmission, and to discover the best frequency to use. It was agreed to make radio-sonde observations as soon as equipment was available and a satisfactory technique had been evolved.

(*e*) *Instruments*.—It was agreed to provide the ships at first with the standard instrumental equipment necessary for making the observations needed for the modified Code Form 2,[1] additional equipment being added later as required.

The Marine Superintendent, Meteorological Office, asked D.N.M.S. on 24 July 1940 to place certain suggestions before the Admiralty. These related to recommendations as to type of ship and included a suggestion that the ship chosen should fly the White Ensign and be offensively armed, the armament to be as heavy as possible and to include anti-U-boat apparatus and depth charges. A U-boat would think twice of attacking a ship, especially a small ship, obviously so armed. A ship thus armed might perhaps act in the N. Atlantic as both an anti-U-boat and meteorological ship. The reply was that there would be very little choice of ships and the ideal was unlikely to be obtained. The ships would not be under the White Ensign and would be requisitioned by the Admiralty on a contract basis, the owners being responsible for the manning and storing of the ships.

As a result of this reply, the Marine Superintendent stated that the whole aspect of the case was altered and that many of the points on which agreement had been previously reached would need reconsideration. The following points were emphasised :—

(*a*) A merchant ship of 2,000 to 3,000 tons with a speed of 10 knots would only be suitable for this duty if very heavily armed, fitted with Asdic and depth charges and if under the White Ensign and thus able to take immediate offensive action. A ship under the Red Ensign could take only defensive action and carry only a gun aft. Such ships have no reserve speed, are slow on the helm, have relatively deep draught and are an easy target for U-boats, surface raiders and aircraft. It was, moreover, intended that the ship should send a W/T report every four hours so that she would be inviting attack, whereas other merchant ships of this type would be convoyed and would maintain W/T silence. The meteorological ship would be masquerading as a merchant ship and yet carrying out non-mercantile duties and would, therefore, rightly be liable to be sunk at sight.

(*b*) The ships should be under the control of D.M.O. (through the Air Council if necessary) in consultation with the Admiralty.

The Air Council took up with the Admiralty, on 7 August 1940, the question of offensive armament for the ships, and D.M.O. also took it up with D.N.M.S. The latter replied that as the ships would be under the Red Ensign, they could not be 'offensively' armed. As, however, the enemy had already defied International Law by adopting a policy of attacking merchant ships without warning, the Law permitted a 'defensively' armed merchant ship to open fire

[1] I.M.O. Publication 9.

on an enemy surface vessel, submarine or aircraft, even before she had attacked or demanded surrender, if doing so would tend to prevent her gaining a favourable position for attacking. The D.N.M.S. said that the question of armament had been referred to the appropriate Naval Staff Divisions and, if the proposed armament was approved, it was considered that the ship would not have to face any greater risk than that encountered daily by other ships in the Atlantic.

At the beginning of September, the Admiralty notified the allocation of S.S. *Arakaka* and S.S. *Toronto City* as weather reporting ships in the Atlantic. The code name 'Panther' for the operation was agreed for use within the Meteorological Office and the Naval Meteorological Service. The gross registered tonnage of S.S. *Arakaka* was 2,379 and that of S.S. *Toronto City* was 2,486. Each was armed with a 4-in. gun mounted in the stern, two Hotchkiss machine guns, one anti-aircraft kite and four anti-aircraft rockets.

Staff

It had been decided that the Meteorological Office should provide a highly qualified and experienced Scientific Officer in each of the two ships. D.N.M.S. also proposed to place one R.N.V.R. officer in each ship. The officers chosen by D.M.O. were a flight lieutenant in the Meteorological Branch of the R.A.F.V.R. and a civilian Technical Officer. The former was promoted to squadron leader on taking up his appointment and, as the question of compensation in the event of a casualty to a civilian could not be satisfactorily settled, the civilian was commissioned as a flight lieutenant in the R.A.F.V.R. The naval officers appointed, were withdrawn after the first voyage of each ship. This necessitated further assistance being given to the two officers and a corporal meteorologist, R.A.F.V.R., was posted to each ship. A second corporal later reported for duty with the *Toronto City*.

Equipment

The equipment of the *Arakaka* and the *Toronto City* on their first voyage was reported to be :—

Assmann psychrometer.
Three-cup electric anemometer with receiver and batteries.
Ship's thermometer screen.
Theodolite (Keuffel and Esser) with assorted pilot balloon equipment.
Barometer, with gold slide.
Barograph.
Canvas bucket.
Thermometers (assorted).
Bicycle lamp.
Cloud-observing goggles.

Additional instruments, later supplied to the ships, were :—

Hair hyrograph.
Lumby sea sampler.
Binoculars.
Distant reading psychrometer.
Bimetallic thermograph.
Two additional cup electric anemometers.
Airmeter.
Gold visibility meter.

Organisation

The ships were chartered by the Admiralty under Charter Party T.99A. Except for bunkering, arrangements for running the ships remained the responsibility of the owners. The ships operated in turn, each going out and returning from the selected area in convoy and making weather reports by W/T only when in the area, *i.e.*, when not in convoy. The S.S. *Arakaka* set out on her first voyage on 16 September 1940 and the S.S. *Toronto City* on 3 October 1940. Messages were passed via Portishead, each ship being provided with its own individual schedule giving call-signs, frequencies and times of transmission which were different for each transmission and for each ship. The call-signs on these schedules were only to be used when transmitting weather reports. Each ship was provided with a special meteorological recoding table, copies of which were held only by S.S. *Arakaka* and *Toronto City*, the Admiralty, the Meteorological Office and the Controller, Canadian Meteorological Service. The weather reports were recoded with these tables, the final form when transmitted appearing as a message in the Merchant Navy Code. For transmitting reports, the ships were instructed to call Portishead at the time shown in the schedule; if contact was not established, they were to continue to call Portishead for 25 minutes. If contact had not been made by the end of that time, they were to broadcast the message and close down and add the message to the next routine transmission.

The meteorological officer was empowered to request the Master to go to any particular part of the area; the Master was to comply with the request provided he was satisfied that the safety of the ship would not be endangered.

Routine meteorological observations were made at the then standard synoptic hours:—01, 04, 07, 10, 13, 16, 18, 22 G.M.T. They included wind; weather (past and present); cloud amount, height and type; state of sea and swell; wet and dry bulb temperatures; ship's course and speed; pressure and barometric tendency; visibility and sea temperature. In addition, pilot balloon and nephoscope observations were made when possible.

It soon became clear that there were serious disadvantages in operating the ships from ports in the United Kingdom. At a meeting held to discuss the results of the first voyage of the *Arakaka*, the Chairman (D.N.M.S.) said that arrangements were being made to operate the ships from St. John's, Newfoundland, and to bring them back to an English port every three months. The proposed routine from St. John's was five days on passage out, 18 days in the area, five days on passage back and seven days in harbour; this would give a safety margin to allow for delay caused by bad weather. As a result of this change, the reporting area was moved to the following limits:—

53° N. 25° W.; 50½° N. 35° W.; 45° N. 35° W.; 45° N. 28½° W.; 51° N. 25° W.

The W/T equipment of each ship consisted of one HF transmitter and two receivers. Three wireless operators were carried. It was intended that communications be made with Portishead in the same way as for ordinary merchant shipping. Great delay in making contact with Portishead was experienced on the first voyage of both ships, but conditions improved in later voyages. The ships received satisfactorily the Home Fleet Synoptic and the Halifax Atlantic Fleet Synoptic messages.

Surface weather reports were coded in a modified and extended form F.232.[1] The information additional to that provided by ordinary codes was as follows:—

(*a*) Time of passage of cold front and drop of temperature at the front.
(*b*) Time of commencement and time of cessation of rain (this did not apply to showers, but to the more general types of rain).
(*c*) Height of base of cloud in hundreds of feet: two figures.
(*d*) Humidity: two figures.
(*e*) Sea temperature: two figures.

The cypher used was named NAPA and had a life of approximately four months.[2] The original allocation of copies was two to D.N.M.S., two to the Meteorological Office, one to each reporting ship and three to Canada.

Each ship carried the following codes:—

(*a*) Ordinary merchant ship set of books including Merchant Navy Code and ordinary recoding tables. These were used for reading ordinary messages for British merchant ships.
(*b*) Confidential Meteorological Code and recoding tables—for use in reading Fleet Synoptic messages.
(*c*) A special Meteorological Code with recoding tables (NAPA) used for sending weather reports.
(*d*) A special recoding table for use with the Merchant Navy Code. Copies of this code were held by both ships, Admiralty and C.O.A.C. This code was used for any messages, other than weather reports, to Admiralty or C.O.A.C.

Liaison with the Canadian Meteorological Service

The D.M.O. gave the Controller of the Canadian Meteorological Service details, in November 1940, of the Panther Scheme and the intention to base the ships at St. John's, Newfoundland. First direct contact with the meteorological office at Newfoundland Airport and with the Controller in Toronto was made in January 1941 by the meteorological officer on the *Toronto City*. The aim of his visit to Toronto was to ascertain the position with regard to the supply of radio-sonde equipment. The Controller of the meteorological office in Toronto assured him that he could count on the supply of necessary stores and equipment.[3]

The Loss of the Two Ships

The S.S. *Arakaka* and the S.S. *Toronto City* were sunk by U-boats in mid-Atlantic: the former on 23 June 1941, after having completed five voyages, and the latter on 1 July 1941 after six voyages.[4]

Radio-Sonde and Radio Wind-finding

Early Developments (1939–1940)

The essential feature of a radio-sonde is a small airborne transmitter radiating signals which are modulated at audio-frequencies; these frequencies are controlled by elements sensitive to changes in temperature, pressure and

[1] *See* I.M.O. Publication No. 9, 3rd Edition 1946.
[2] A.M. File S.58250.
[3] A.M. File S.58250/II.
[4] Ad. B.R.1337. *See* Appendix 20 for an account of the scientific investigations undertaken on board the two ships.

humidity. By measuring the audio-frequencies at a receiving station on the ground, the values of temperature, pressure and humidity aloft may be determined. A parachute is attached to the radio-sonde, which is suspended from a small balloon filled with hydrogen, and when the balloon reaches the bursting height, the parachute opens and the instrument floats gently down to earth and may be retrieved for future use, after re-conditioning and re-calibration.

If the signal radiated by the airborne transmitter is received at two or more direction-finding (D/F) stations equipped with a specially designed rotateable aerial system, the bearing of the transmitter from each station may be observed; by plotting cross-bearings at minute intervals, the balloon's displacement, and thus the upper winds, may be determined.

In this section, stations at which observations are made using either radio-sonde or radio wind-finding methods, or both, are called 'upper air stations'.

Radio-Sonde : The outbreak of war stressed the importance of establishing an upper air station in the Shetland Islands as well as one in the Scilly Islands which was already being considered. To start observations at Scilly, a contract had been placed in Finland for the supply of Vaisäla radio-sondes, but political developments made it necessary to arrange for an alternative source of supply especially as it was realised that, owing to its specialised design, the British instrument which was being developed by the National Physical Laboratory could not be ready for manufacture for at least a further year; French (Bureau) instruments were therefore ordered.[1] Using stocks of Finnish radio-sondes, soundings at 0500 G.M.T. daily were started at Scilly in February 1940 and in the following April, when enough French equipment had been received, soundings at 0600 G.M.T. daily were started at Lerwick Observatory in the Shetland Islands. The depletion of stocks of Finnish transmitters, however, and the cessation of supplies from France consequent on the outbreak of active warfare on the continent resulted in a breakdown of soundings at Lerwick in September and interruptions in the programme at Penzance (which took the place of Scilly in October 1940). Fortunately by December 1940, an early type of British transmitter (Mark III) became available in sufficient quantities to permit the resumption of daily soundings at both stations.

Radio Wind-finding : The D/F method of observing the movement of an airborne transmitter for the computation of upper winds had been tested in April 1939 at Larkhill, where two D/F sites at Elston and Lavington had been set up, and a regular programme of observations at 0400 G.M.T. on weekdays had been started in July.[2] During the summer a third D/F site, at Bowerchalke, was chosen and calibrated, development work at the National Physical Laboratory having shown that site errors were likely to be important. In October 1939, a pressure unit was incorporated in the airborne transmitter in order that the height of the transmitter could be determined with some certainty. As the short single base-lines then in use were not regarded as entirely satisfactory, a search was made during the winter for further suitable sites in the neighbourhood of Larkhill, and in February 1940, the base line was extended to Lavington-Chitterne. In May, successful trials of a triple station array were made and a technique was developed for the simultaneous observation of bearings of the airborne transmitter at three D/F sites and for reporting the

[1] A.M. Files 817233/38 and 7522/39.

[2] A.M. File S.39512.

observations by telephone to the central office at Larkhill; this technique was adopted as standard procedure in July 1940. In December 1940, the programme of observations was increased to at least two daily, at 0600 and 1300 G.M.T., with a further observation at 1700 G.M.T. whenever required.

Expansion (1941–1945)

The upper air organisation continued expanding during 1941–42. The ultimate objective, which was to cover the British Isles with a network of upper air stations at intervals of some 200–300 miles and to make observations at each station every six hours, could obviously not be attained at once; it took time to train personnel in the specialised technique and to manufacture enough instruments; moreover the requirements of personnel for upper air work had to be balanced against requirements for other work of the Meteorological Office.

As a preliminary to the expansion of the operational programme it was decided, in October 1940, that Larkhill should take over from Kew Observatory the work of calibrating wind-finding transmitters retrieved after flight and returned for re-conditioning. Larkhill would thus deal with all retrieved transmitters whilst Kew would handle all new transmitters received from the manufacturers; calibration of radio-sondes at Larkhill started in July 1942. Later, in January 1943, in order to ensure that the upper air programme would not be put out of commission by enemy action against Kew, a second calibrating plant was installed at Larkhill and stocks of new transmitters were divided between Kew and Larkhill, whilst spare components were held at M.O.4.

Because of the time required to place contracts and to manufacture radio-sondes, *i.e.*, of transmitters plus meteorological elements in sufficient quantities for routine use, the radio wind programme dependent only on a transmitter expanded more rapidly in 1941 than the radio-sonde. A conference in February 1941 decided that :—

(*a*) The five-mile base lines at Larkhill were to be replaced by a triangular array with 20 mile separation between sites.

(*b*) Observers were to be posted to each D/F site for a fortnight at a time.

(*c*) Additional radio wind-finding stations were to be established in the Shetland Islands and in the vicinity of Preston, Lancashire.

(*d*) Ascents were to reach a height of at least 14 km.

During the period of expansion the National Physical Laboratory continued to help in the selection and calibration of D/F sites, drawing up for the guidance of the Meteorological Office personnel a specification of a D/F site suitable for wind-finding and also supplying instructions for acceptance tests of new D/F equipment and routine test work, for which the Meteorological Office assumed responsibility in February 1942.[1]

The first result of expansion was the opening in April 1941 of a new radio wind-finding station at Fazakerley, Liverpool, with satellite D/F sites, selected by the National Physical Laboratory, at Chester, Middlewich and Walner Bridge, where the D/F receivers were provisionally installed in marquees. Routine observations were made at 0600 and 1500 G.M.T. daily. The Meteorological Office staff at Fazakerley were also assigned the task of making the

[1] A.M. File S.69118/1.

special ascents for 'Albino' to determine upper winds at a fixed level; this project was indefinitely suspended in August 1941. In the summer of 1941 sites for D/F work in the Shetland Islands were selected and requisitioned; a search was also made for sites in Northern Ireland but none were set up in that area.

Production of radio-sondes had by then reached the stage where programmes of upper air temperature observations could be increased. Where possible the radio-sonde transmitter was used as a source of signals to be located by D/F methods so as to obtain upper wind reports simultaneously with temperature, pressure and humidity observations. Certain stations, however, had no facilities for radio wind-finding; at others, D/F sites were set up before radio-sonde transmitters could be made available; thus it came about that these types of upper air observations were reported :—

(*a*) Simultaneous temperature, etc., and wind; this was known as a full radio-sonde ascent and coded as a PRAWT.

(*b*) Temperature, etc., but no wind; this was known as a radio-thum and coded as a PRAT.

(*c*) Wind but no temperature, etc., this was known as a radio-wind and coded as a PRAW.

Expansion was rapid during the 14 months from July 1941. At Larkhill, a third balloon ascent for radio wind-finding was added in July 1941, the times of ascent being altered to 0800, 1600, 2400 G.M.T. (these times were brought forward one hour in November); simultaneous radio thum and wind observations were introduced, at midnight in August and at 1600 G.M.T. in September, and by August 1942 all three soundings were being reported in PRAWT form. At Fazakerley, a third (radio wind) ascent at 2400 G.M.T., was added in September 1941, and in August 1942, the night observation (by then at 2000 G.M.T.) was converted to a PRAWT sounding. At Lerwick, a second radio thum observation (PRAT) at 1400 G.M.T. was started in March 1942 and following the installation of D/F equipment in April 1942, both observations were converted to PRAWT soundings; a third PRAWT sounding was added in July 1942. A radio wind station was set up at Downham Market where, in January 1942, two ascents (PRAW) daily at 0400 and 1200 G.M.T. were started; in July 1942, the morning observation (by then at 0500 G.M.T.) was converted to a PRAWT sounding and a third ascent (PRAW) at 2000 G.M.T. was added. Penzance continued to report one PRAT daily at 0500 G.M.T. until September 1942, when a second PRAT report at 2000 G.M.T. was introduced. By September 1942, the following daily programme of upper air radio observations was in operation :—

	0500	1200	2000
Larkhill ..	PRAWT	PRAWT	PRAWT
Lerwick ..	PRAWT	PRAWT	PRAWT
Fazakerley ..	PRAW	PRAW	PRAWT
Downham ..	PRAWT	PRAW	PRAW
Penzance ..	PRAT	—	PRAT

In March 1943 the times of observation were changed to 0000, 0600 and 1200 G.M.T. (except at Lerwick when the last sounding was made at 1800 G.M.T.) and the programme at Fazakerley was raised to three PRAWT reports.

At various times during the war short interruptions in the programme at some stations were necessitated by breakdowns in supplies of transmitters or balloons but interruptions on this account were minimised by the policy of accumulating a reserve of about 100 calibrated transmitters at each upper air station.

The fall of Malaya made it essential to exercise the utmost economy in the use of rubber balloons; consequently it was decided in early 1942 to aim at obtaining a full PRAWT report with every balloon expended. The difficulties, created by the changed situation in the Middle and Far East, of ensuring supplies of transmitters to overseas stations led to the indefinite postponement of any plans to open upper air stations in the Middle East. In August 1942, experience gained of the uses of upper air observations showed the need for a closer network of upper air stations over the British Isles, a need which would be partly met by opening stations at Stornoway and Leuchars; observations from a station in Eire, at Valentia, were also needed very badly.

Before the war, Eire had been negotiating the purchase of French (Bureau) sondes but, owing to delays in communications and arrangements, no instruments were delivered before the fall of France in the summer of 1940. As a result of subsequent negotiations between the Eire Meteorological Service and the British Meteorological Office, it was decided to open an upper air station at Valentia in July 1942 using, despite shortages of supplies, British equipment.[1] The absence of a supply of electricity at Valentia for operating the radio receiving equipment created a delay which was not overcome until the winter of 1942–43 when an A.C. generator was released from the United Kingdom and consigned to Valentia. The lack of trained staff in Eire and the difficulty of sparing British specialist staff from operational duties led to further delays and it was not until July 1943 that Meteorological Office staff could be sent to Valentia to start training Irish personnel. However, a routine programme of two PRAT reports (at 0000 and 1200 G.M.T.) was started in August 1943 subject to occasional breaks due to difficulties in maintaining supplies of equipment—and in August 1944 the Eire Meteorological Service assumed sole responsibility for the commitment.

Owing to limitations of staff and supplies of transmitters, the policy of opening new upper air stations at Stornoway and Leuchars could only be carried out at the expense of programmes at existing stations. In 1943, however, United States personnel arriving in the United Kingdom were bringing with them mobile upper air stations. In July 1943, the U.S. authorities made an offer, which was gladly accepted, to lend personnel to help at existing British upper air stations and to undertake exclusive maintenance of the upper air station at Penzance. This assistance made possible the desired expansion of the radio-sonde network and also released the British staff for Valentia; moreover with the assistance of ten U.S. personnel in the calibration section at Larkhill the output of transmitters was increased to provide for the augmented programme of soundings.[2]

Penzance was taken over by the Americans in September 1943 and the programme was increased to four 'RAOB' soundings daily (RAOB was the U.S. equivalent of PRAT). In October the Americans, using U.S. mobile

[1] E.4650/46.

[2] A.M. File S.69918/II.

equipment, set up an upper air station at Leuchars making two RAOB reports daily at 0600 and 1800 G.M.T. and increasing the programme to four soundings in January 1944. In February 1944, the Americans opened an upper air station at Stornoway where an initial programme of two RAOB reports was increased to four in March 1944. At that time U.S. personnel began to operate mobile radio wind-finding equipment (S.C.R. 658) at Nutts Corner in Northern Ireland; in August 1944 similar equipment was introduced at Stornoway and used for routine 'RAWIN' observations (RAWIN = PRAW) at 0000 and 1200 G.M.T.

At British upper air stations the increased strength of personnel enabled programmes to be raised to four PRAWT reports at Larkhill and Fazakerley in August 1943 and at Downham Market in January 1944. By March 1944 the daily programme of upper air radio observations was as follows :—

	0000	0600	1200	1800 G.M.T.
Larkhill ..	PRAWT	PRAWT	PRAWT	PRAWT
Lerwick ..	PRAWT	PRAWT	PRAWT	PRAWT
Fazakerley ..	PRAWT	PRAWT	PRAWT	PRAWT
Downham ..	PRAWT	PRAWT	PRAWT	PRAWT
Penzance ..	RAOB	RAOB	RAOB	RAOB
Valentia ..	PRAT	—	PRAT	—
Leuchars ..	RAOB	RAOB	RAOB	RAOB
Stornoway ..	RAOB	RAOB	RAOB	RAOB
Nutts Corner	Irregular RAWIN.			

During this period preparations were made, in collaboration with the Royal Norwegian Air Force, for setting up a radio-sonde station on the island of Jan Mayen, where two PRAT soundings daily at 1100 and 2300 G.M.T. were started in May 1944.

The use of radar for wind-finding in place of the D/F method had been considered for some time. In the radar method a radio pulse is directed towards a metallised reflector suspended from a free balloon and is reflected back to the ground where it is received after a measurable time delay depending on the distance of the balloon from the transmitting/receiving station; values of the range, azimuth and elevation of the balloon at any instant may be observed and hence the balloon's displacement, and therefore the upper winds, may be determined. Besides giving more detailed information and having greater accuracy than the D/F method, wind-finding by means of radar effects an economy in staff by removing the need for dispersal of personnel to remote D/F sites. Trials of the radar method using War Office equipment A.A. No. 3, Mark 2, more usually known as G.L. III, were made at Larkhill in 1943 and the success of these trials led to the decision to obtain the equipment for routine use at Meteorological Office upper air stations. Shortage of supply was a limiting factor but in June 1944 a set at Larkhill was transferred to Shoeburyness, where it was primarily required in connection with Ballistic investigations but was also used for routine observations of upper air (PILAR reports) at 0500, 1500 and 2100 G.M.T. In October 1944 another set was brought into routine use at Fazakerley. Equipment for other upper air stations was not delivered until after the war.

The principal development in 1944, however, was the deployment of personnel for the landings in Europe where it was necessary to establish upper air stations as the advance proceeded. These stations were provided by the United States authorities using their mobile equipment, but the withdrawal of U.S. personnel

from Britain created difficulties in maintaining the upper air stations in this country owing to shortages of staff and ground equipment. It was agreed, late in 1944, that U.S. equipment in use at British stations would be left intact for operation by British personnel who would be trained in American technique. Nevertheless, certain reductions in the upper air programme at stations in the United Kingdom were inevitable: at Leuchars and St. Mawgan (to which the Americans had transferred the station at Penzance in August 1944) the programme was reduced in November 1944 to two RAOB reports, at 0600 and 1800 G.M.T.

For the remainder of the war, efforts, as far as upper air work was concerned, were mainly directed towards training staff in the special techniques. In December 1944 British staffs were sent to Stornoway to be instructed in American methods; on completion of training some of these staff were posted to Leuchars (March 1945) and Nutts Corner (June 1945) to take over the upper air stations from the Americans while the remainder replaced U.S. personnel at Stornoway (June 1945). Unfortunately from August onwards supplies of American equipment to the United Kingdom became very irregular and programmes at Stornoway, Leuchars and Nutts Corner were subject to frequent interruption until after the end of the war, when the stations were re-equipped with British equipment.

In the spring of 1945, a school was opened at Larkhill solely to train staff of the Meteorological Office in the techniques of upper air observation by means of radio-sonde and radar; it was transferred in June 1945 to Downham Market. At the end of March 1945, with the prospect of an output of trained staff from the Training School, it was decided to release experienced staff even at the expense of a temporary reduction in home programmes, in order to open an upper air station at Uccle in Belgium using British equipment; an initial programme of one sounding (PRAT) at mid-day was rapidly increased to four soundings daily; at the same time Belgian personnel were trained and were able to assume sole responsibility for the station in June. In April 1945, when the American upper air station at St. Mawgan was closed, British staff re-opened the station at Penzance using British equipment.

On VJ Day the upper air programme was as follows :—

	0000	0600	1200	1800 G.M.T.
Larkhill ..	PRAWT	PRAWT	PRAWT	PRAWT
Lerwick ..	PRAWT	PRAWT	PRAWT	PRAWT
Fazakerley[1] ..	PRAWT	PILAR	PRAWT	PILAR
Downham[1] ..	PRAT	PRAWT	PRAT	PRAWT
Penzance ..		PRAT		PRAT
Valentia ..	PRAT		PRAT	
Leuchars ..		RAOB		RAOB
Stornoway ..		RAOB and RAWIN		RAOB and RAWIN
Nutts Corner..		RAWIN		RAWIN
Jan Mayen ..	PRAT		PRAT	
Shoeburyness[2]		PILAR	PILAR	PILAR
Uccle ..	PRAT	PRAT	PRAT	PRAT

[1] The full programmes of four PRAWT reports at Downham and Fazakerley, reduced temporarily in order to release staff for Uccle and Penzance, were restored in September and October 1945 respectively when newly trained staff from the school became available.

[2] These observations were made at 0500, 1500, 2100 G.M.T.

Meteorological Reconnaissance Flights[1]

At the beginning of 1939, the Meteorological Office began to investigate means of obtaining weather information over the sea, especially the Atlantic, to replace ships' reports which would clearly be substantially curtailed or even completely suppressed in the event of war. Three possible sources of information were considered :—

(*a*) *Reports from special ships.* The British and French Meteorological Services proposed, at a Signals and Meteorological Conference in Paris in August 1939, that the transmission of observations, including upper air observations, by certain ships only (surface craft or submarines) should be studied as a matter of urgency by the Admiralty and the French Ministry of Marine.[2]

(*b*) *Observations from aircraft crossing the Atlantic.* Aircraft would continue to cross the Atlantic, probably in increasing numbers, as it was most important that transatlantic air mail and passenger services should continue to operate in war-time and aircraft manufactured in Canada were to be delivered by air. This vital stream of aircraft did in fact grow to unforeseen proportions, especially after the entry of the United States into the war, and much useful meteorological information was obtained in this way.

(*c*) *Observations made from aircraft on patrol over the sea.* An early attempt was made to systematise and direct the observation of weather over the sea and its reporting by the crews of Service aircraft on reconnaissance duties over the Atlantic, and a practice originated which in its essentials has remained in use.

Nevertheless, the Meteorological Office realised from the outset that meteorological reconnaissance, because of its demands, was specialist work and that the ideal arrangement would be to have special flights for that purpose. The Air staff fully recognised the need for special flights but at that time the provision of special aircraft was impossible as barely enough aircraft were available for necessary operational duties. A counter suggestion that a few civil aircraft might be temporarily allocated for meteorological reconnaissance over the sea was examined, but civil aircraft could no more easily be spared than service aircraft and none were made available for such flights.

As the war progressed, Bomber Command became increasingly anxious to secure accurate forecasts of weather conditions over the North Sea and North Germany. At that time, before the development of the special devices used later in the war, their night and more especially their daylight operations were very closely related to the weather, both for identification of the target and, in the case of daylight sorties, for the safety of cloud cover *en route*, and their forecasting requirements were correspondingly exacting. Moreover, the imposition of wireless silence on ships made it very difficult to forecast Atlantic weather, a knowledge of which was needed not only for R.A.F. operations, but also for those of the Royal Navy, and was of great importance for forecasting conditions at home. Beset by numerous requests for more accurate forecasts over the Atlantic, North Sea and Germany, the Meteorological Office repeatedly emphasised the need for observations over these areas, particularly routine

[1] *See also* Chapter 6.

[2] A.M. File S.48945.

aircraft observations ; observations obtained from aircraft engaged on other Service duties were collected and broadcast but they were intermittent and often referred to regions too near to the coast. Meanwhile, Intelligence had revealed that the enemy was making meteorological reconnaissance flights over the seas surrounding the British Isles and elsewhere in order to supplement his surface network of meteorological information.

The time had clearly come to investigate more closely the means of increasing our own sources of meteorological information, and the Expansion and Re-equipment Policy Committee agreed on 4 October 1940 that three meteorological flights should be formed to make weather observations over the sea. Nos. 403, 404 and 405 Flights (later renumbered Nos. 1403, 1404 and 1405 Flights), each of three Blenheim III aircraft, were established in late 1940 and were located at Bircham Newton, St. Eval and Aldergrove respectively. Flights started in December 1940 and were operating regularly by the end of April 1941. In March 1941, all the meteorological flights were placed under the control of Coastal Command and, in August 1941, the flights were granted operational status.

The initial Meteorological Office plan was for two sorties a day from each base to a distance of about 500 statute miles. At first only 200 miles could be achieved with the Blenheim aircraft but the outward range was increased to 350 miles after the aircraft had been modified and the crews had gained more experience. With the number of aircraft provided, only one sortie a day by each flight could be made but this task was performed with great regularity during 1941. It was recognised that the Hudson was the appropriate aircraft for meteorological reconnaissance and in August 1941 an establishment of Hudsons was obtained. Conversion from Blenheims to Hudsons was carried out at the units but was rather slow and, after the United States entered the war in December 1941, the flow of Hudsons from America fell off to such an extent that the meteorological flights were rarely up to establishment. The shortage of Hudsons led to a change in equipment in November 1942, from Hudson to Hampden, but enough suitably maintained Hampdens were not generally available to meet requirements. In June 1943, the E.R.P. Committee approved the use of Halifax V aircraft for long range reconnaissance (radius of action 700 nautical miles) and Ventura V aircraft for medium range reconnaissance (500 nautical miles), but owing to difficulties in providing additional aircraft and crews, conversion had to be undertaken in stages covering several months. In April 1944, Coastal Command re-equipped the medium range reconnaissance units with Hudson III aircraft, but much mechanical trouble was given by these aircraft and in early 1945, the medium range units were re-equipped with Fortress II aircraft.[1] The Halifax V aircraft also gave a good deal of mechanical trouble at first ; moreover, if the engines failed sooner than four hours after take-off, height could not be maintained with full petrol load. The length of the patrols had, therefore, to be shortened temporarily, and the aircraft be equipped with bomb bay tanks which could be jettisoned. This modification was completed by the beginning of 1945. Soon after, Halifax V were replaced by Halifax III aircraft which had greater power and a more reliable performance, and these aircraft, fully modified for the meteorological role, were the standard equipment for meteorological reconnaissance squadrons at the end of the war.

[1] A.M. File S.85372.

The effort devoted to meteorological reconnaissance progressively increased, both in the number of special flights allocated for this role and in the range and frequency of sorties. Additional flights (Nos. 1407 and 1408) were formed late in 1941 to operate from Reykjavik and Wick respectively and, in January 1942, the aircraft establishment of each squadron or flight was increased to six in order to provide for two sorties a day. Second sorties were rarely flown, however, except from Aldergrove where Blenheims were retained for a long while in addition to the Hudsons. Provision was made for more frequent flights of increased range from St. Eval and new sorties westward from Gibraltar in connection with the North Africa landings in November 1942. This increase in effort was not maintained long after January 1943 on account of Hudson deficiencies; but as a result of proposals for an increase in the number of flight tracks from six to ten, and in the minimum range from 450 to 900 nautical miles, with two sorties daily on each track, the E.R.P. Committee approved in June 1943 the following establishments :—[1]

- No. 517 Squadron (Brawdy), incorporating the former No. 1404 Flight, 24 Halifax V.
- No. 518 Squadron (Tiree), incorporating the former No. 1405 Flight, 16 Halifax V.
- No 519 Squadron (Wick), incorporating the former No 1408 Flight, 12 Ventura V.
- No. 520 Squadron (Gibraltar), 8 Halifax V.
- No. 521 Squadron (Bircham Newton), incorporating the former No. 1403 Flight, 6 Ventura V.
- No. 1407 Flight (Reykjavik), 6 Ventura V.

The units based at Bircham Newton, St. Eval, Aldergrove, and Wick usually managed one sortie a day during 1943, although there were occasional gaps, and from May to September there were long periods when one or more of these units made two sorties a day with fair regularity. Sorties from Iceland and Gibraltar, however, were very irregular and were maintained largely by Coastal Command placing aircraft of other squadrons at the disposal of the meteorological flights. The expansion planned in August 1942 and approved in June 1943, was first partially realised in September 1943 when 700 nautical mile sorties were introduced from Tiree, where training and conversion of crews to Halifax V aircraft was also taking place. At about that time, the U.S.A.A.F. provided Fortress aircraft to undertake one 700 nautical miles sortie a day, later increased to two a day, over the S.W. Approaches; this help was given to speed up the expansion and cover the need for meteorological information from this area until Coastal Command were able to assume the responsibility. Expansion was still incomplete by the beginning of 1944. There were still no long-range sorties from Gibraltar and on additional tracks in the South Western and North Western Approaches. This was due mainly to the large amount of modification required by the Halifax V to adapt it for the meteorological role, but these modifications had by then been specified in detail and rapid progress was expected in the delivery of modified aircraft. In fact, progress was steady but not rapid. After an offer by the U.S.A.A.F. in May 1944 to continue two sorties a day over the S.W. Approaches on a permanent basis, the establishment

[1] A.M. File S.77460.

of British aircraft was readjusted so as to provide two sorties daily on each of two different tracks from Tiree and two sorties daily from Brawdy. In June 1944, the establishment of No. 1407 Flight was increased by another three Hudson III aircraft in order to increase the frequency of flights from Iceland, and the Flight was renumbered No. 251 Squadron. In September 1944, the U.S.A.A.F. effort was increased to four flights daily, including a daily shuttle service between the United Kingdom and the Azores.[1]

Meteorological Air Observers : In the early stages of meteorological flights, navigators made the meteorological observations as trained meteorologists were not available. In September 1942, however, the Meteorological Air Observer Section of the G.D. Branch was formed and experienced Meteorological Office personnel were recruited and trained in the technique of making observations from aircraft. The first officers were posted to the meteorological squadrons and flights in June 1943 and were followed by N.C.O.s shortly afterwards.[2]

Equipment : The meteorological instruments fitted to the aircraft comprised a strut psychrometer (spirit in glass) fixed on a special bracket, and an aircraft aneroid connected to the pitot-static tube or preferably the static vent. In the Halifax and Fortress aircraft, a meteorological station in the nose of the aircraft, from which an excellent view of the clouds and sky could be obtained, was fitted with a desk and chair, allowing of easy access to the meteorological instruments.

Flight Plans and Procedure : In the first stages, the track was relatively short and the flight plan was a simple one of an outward flight at a general level of about 950 mb. (18,000 feet) to make an upper air temperature sounding (in aircraft not equipped with oxygen the sounding was terminated at 700 mb. (10,000 feet)) and a return flight to base on a reciprocal track at any convenient height. In the autumn of 1943, the introduction of four-engined aircraft allowed the length of each sortie to be almost doubled. The outward leg was increased to 700 nautical miles; the ascent to 500 mb. was still made at the terminal point, but on the first 350 miles of the return on reciprocal track, the general level of flight was 500 mb. At the end of this high level leg, the aircraft descended almost to sea level making a second temperature sounding and returned to base flying at 950 mb. Two soundings were thus obtained on each sortie. In 1944, certain tracks were changed to triangular ones, in which case a sounding was made at each outer corner of the triangle, the first and third legs being flown at 590 mb. and the second leg at 500 mb.[3] The advantage of a track of that shape was that although the aircraft did not penetrate so far out over the Atlantic, better coverage of the Atlantic seaboard was obtained. Exceptions to this rule were Nocturnal, Rhombus and Recipe sorties. In the case of Nocturnal, the relative position of land stations made the straight track preferable, and in the case of Rhombus and Recipe, the tracks were governed by considerations of operational security during most of the war.

In addition to the routine sorties, occasional meteorological reconnaissance flights were made from the Azores by No. 269 Squadron whenever aircraft could be spared from their primary task, and at the end of 1943, whilst No. 518

[1] A.M File S.85372. [2] A.M.O. A.973/42.

[3] *See* Appendix 21 for the tracks flown by meteorological reconnaissance flights and the code name allocated to each.

Squadron was forming, reconnaissance flights, known by the code word Cheap-jack, were made in Catalina aircraft of No. 131 O.T.U. to a point 500 nautical miles west of Killadeas (N. Ireland).

Routine observations of temperature, humidity, weather, clouds, visibility, turbulence and icing were made every 50 miles on the reconnaissance flights. Observations of wind at aircraft heights were made by multiple drift, as far as possible at every third position, with supplementary observations by other methods as often as possible at intermediate observation positions. The sea level pressure was determined at every 200 miles on the low level leg and at the positions of the soundings to 500 mb. To do this, the aircraft descended to near the sea surface, the altimeter was set to the height above sea level and the pressure was read on the altimeter subscale. In the early days of the flights, the height was about 50 ft. and was estimated, but the height of the aircraft was later measured by a radio altimeter and it was then necessary to descend only to about 200 feet above the sea surface.

The observations were entered on a log sheet (Form 2077) and recorded in the General Code for Meteorological Observations from Aircraft. The form of the log sheet varied according to the particular edition of the code in use. A permanent record of the flight was also made as a pictorial cross-section on Form 2816. On the reverse of the form were printed a tephigram and a chart on which the meteorological air observer could insert his own observations during the flight.

The coded observations were encyphered by means of one-time pads and were transmitted by W/T once every hour by the aircraft to base, except in the case of Rhombus which did not report by wireless for aircraft safety reasons.

THUM Flights

At the beginning of the war, two Flights made vertical ascents to obtain observations of upper air temperature and humidity and other meteorological information.[1] Based at Mildenhall and Aldergrove, these Flights were armed with Gauntlet aircraft and equipped with a strut psychrometer and an aircraft aneroid. Each flight made ten soundings a week, all in daylight, to a height of 400 mb. (24,000 feet) and had a splendid record of sustained performance. These flights were known as THUM flights, the code word symbolising temperature and humidity.

The frequency of ascents was increased on 3 September 1939 to two a day, as early in the morning and as late in the evening as possible. The flights began to re-equip with Gladiators in October 1939. When the production of these aircraft ceased, they were replaced by Hurricanes which were issued to the flights for trials as early as 1940, but, owing to the superiority of the slower Gladiators at that time, all available reserves of Gladiators were earmarked for the meteorological flights and it was not until the end of 1944 that Hurricanes were exclusively used for both flights.

In late 1940, the flights at Mildenhall and Aldergrove became independent units, Nos. 401 and 402 Flights respectively, and in March 1941, with the other newly formed meteorological flights, they were absorbed into Coastal Command and renumbered Nos. 1401 and 1402 Flights. No. 1401 Flight was moved to

[1] A.M. File S.61695.

Bircham Newton in November 1941 and the flights were later amalgamated with, or separated from, the larger meteorological reconnaissance units as the location of the latter changed. By the end of 1941, three flights daily—at dawn, midday and dusk—were being made and, with the introduction of Hurricanes, the ascent was extended to 300 mb. (30,000 feet).[1] The operational technique consisted of levelling out at fixed heights (every 50 mbs.) and at the base and top of inversions, in order to make accurate observations of the dry and wet bulb thermometers. The heights of inversions and cloud bases and tops were observed by reading the altimeter or aneroid. Cloud formation, visibility and aircraft icing were observed visually. Immediately after landing, the readings were handed in to the meteorological office at the base for coding and transmission to ETA. These ascents on single-seater aircraft proved very useful during the war and many similar units were formed in overseas Commands. Vertical flights at Gibraltar began in May 1942 and in the Azores in January 1944.

PRATA High Altitude Flights

The development and improvement during the war of high flying technique, and its adoption by Photographic Reconnaissance Units and for daylight bombing necessitated forecasts of upper winds at these new operational heights and of the formation of tell-tale condensation trails. In order to obtain visual meteorological information at these heights and to supplement the network of radio-sonde observations used for determining the height of the tropopause, which has an important bearing on the formation of condensation trails, it was arranged for aircraft ascents to 40,000 feet by Nos. 1401 and 1402 Flights and in N.E. Scotland. Despite the continued shortage of aircraft, authority was given in April 1941 for the establishment of Nos. 1401 and 1402 Flights to be increased by two Spitfire II aircraft, and for the formation of No. 1406 Flight at Wick with a similar aircraft establishment. Ascents by these Flights, known as PRATA flights, were made daily at 1630 G.M.T. or at first light in winter, to the maximum possible height.[2]

Experience showed that the Spitfires II, even when the weight was reduced by the removal of guns, ammunition and armour, could not reach the desired heights and in February 1942, the establishment of each Flight was changed to three Spitfire V aircraft. Even these aircraft were often unable to exceed 38,000 feet without unduly straining the engine, and it soon became clear that the task could only be performed effectively by using an engine proved for high-altitude flying, four-bladed airscrews and extended wing-tips, and by providing a pressure cabin. Accordingly, the establishment of Nos. 1402 and 1406 Flights, and of No. 521 Squadron, into which No. 1401 Flight had by then been absorbed, was amended in February 1943 to three Spitfire VI aircraft.[3] In late 1944, these were replaced by Spitfire VII aircraft which remained the standard equipment until the end of the war.

Progress in realising the flights was at first very slow, owing mainly to the shortage of pilots. By January 1942, No. 1406 Flight were making regular daily ascents, but ascents by Nos. 1401 and 1402 Flights were irregular, the latter having only made two ascents. In January 1942, the flights were combined with those engaged on meteorological reconnaissance flights, thereby forming

[1] A.M. File S.4241.
[2] A.M. Files S.67120 and S.4241.
[3] A.M. File S.73962.

units with larger resources, and at the same time all the meteorological flights were incorporated in the organisation of Coastal Command. By March 1942, high altitude ascents were being made fairly regularly. It was laid down in the winter of 1942 that the time of ascent, which hitherto had been 0630 G.M.T., was to be dawn or civil twilight and in March 1943 the time of daily ascents was amended to 1200 G.M.T. In December 1943, the Flights were asked to make an additional ascent at 0600 G.M.T., or dawn whenever practicable, and the times were later amended to 0500 and 1100 G.M.T. to conform with general practice for upper air soundings by aircraft and radio-sonde.

The task of the pilots of PRATA flights was to make visual observations of the formation of ice and condensation trials, reports on the form, height and thickness of clouds, and readings of the dry-bulb thermometer at stated height intervals, especially in the uppermost layers. The provision of a suitable thermometer and aneroid presented some difficulty, since the spirit in a glass thermometer, hitherto the most reliable instrument, could not be fitted to Spitfires and no aneroids were available of sufficient range for the pressure level, 200 mb. (38,000 feet), reached in PRATA flights. As an interim measure, a gas-filled thermometer was fitted, pending deliveries of a distant-reading Cambridge electrical resistance thermometer, made in October 1941, and I.C.A.N. altimeters (Mark XIVB), specially calibrated at R.A.F. Farnborough, were installed. The meteorological instruments and the technique of their mounting improved continuously. In May 1943, a radiation shield and water-proof mountings for the resistance element of the thermometer were introduced and in May 1944 an improved dial with a double range scale was issued. A new type of electrical resistance thermometer with a balanced Wheatstone bridge was developed and, a trial installation in July 1944 having shown that the instrument was satisfactory, it was installed at all the PRATA flights locally as the thermometers became available. A suitable aneroid, Mark II, and a modified Mark IIB for use with a pressurised cabin, were also developed and, with the introduction of these instruments in April 1944, temperatures were read at specified levels instead of as previously at altimeter heights.[1]

Certain minor changes in location of the THUM and PRATA flights were made within the Coastal Command organisation. No. 1401 Flight, originally at Mildenhall, was transferred in October 1941 to Bircham Newton where, in June 1942, it was absorbed into No. 521 Squadron. In August 1943 the PRATA (Spitfire) element was transferred to Fighter Command as No. 1401 Flight and based at Manston in order to re-arm with Spitfire IX before moving to Brussels in January 1945 under 2nd T.A.F. The THUM element of No. 521 Squadron moved to Langham in November 1944 and stayed there until the end of the war. No. 1402 Flight, originally at Aldergrove, was transferred to Ballyhalbert in December 1944 and No. 1406 Flight, originally at Wick, where it was incorporated in No. 519 Squadron, was transferred with the Squadron to Skitten in December 1943, returning to Wick in November 1944.

PAMPA Reconnaissance Flights over Enemy Territory[2]

The need for meteorological reconnaissance flights over enemy territory in war-time was recognised as early as April 1938 when the question was raised at the 4th meeting of the R.A.F. Meteorological Policy Committee.[3] At the

[1] A.M. File S.84208. [2] *See also* Chapter 4. [3] A.M. File S.45354.

beginning of the war, Photographic Reconnaissance Units operating over enemy territory gathered useful information but it became clear that a crew on an operational mission lacked the freedom of action necessary for a proper investigation of meteorological conditions. Shortage of adequate aircraft and trained personnel presented obstacles to meeting the requirements for purely meteorological flights but, as the weight of the bombing offensive grew, losses and wasted efforts due to adverse weather became increasingly expensive, and it was decided to implement the recommendations of the Inspector-General in May 1941 to provide meteorological flights over Germany. In August 1941, therefore, the establishment of No. 1401 Flight was increased by the addition of two 'F' type Spitfires to be used specifically on meteorological flights involving deep penetration over enemy territory.[1]

The Meteorological Office, in consultation with the operational Groups concerned, surveyed the technical requirements of the new flight and agreed that a broad survey from about 30,000 feet of the weather experienced in penetrating well into enemy territory was required. One sortie daily was to be made, starting in the morning so that the aircraft would land in time for the information obtained to be used in planning the bombing operations for the same night. The route was not to exceed 1,000 miles with the Spitfire 'F', triangular or many-sided, it would vary according to the weather situation and the target for the night. Observations were to be made every 100 miles and supplemented by observations of intervening significant weather phenomena.[2]

The first of the flights, which were known by the code name PAMPA, was made on 7 November 1941. The aircraft failed to return and flights were discontinued until a larger establishment and experienced personnel could be provided to ensure regular and fruitful operation. It was recognised that the most suitable aircraft for the PAMPA task was the twin-engined Mosquito which carried a crew of two, and on 19 February 1942, the E.R.P. Committee allocated two Mosquito IV aircraft to No. 1401 Flight with very high priority. Owing to shortage of pilots and aircraft, however, it was not until the end of May 1942, that sorties could be made whenever they were needed. By June 1942, three Spitfires and two Mosquitoes were based at Bircham Newton to meet the PAMPA commitment and it had been arranged to post one trained pilot to the Flight each month. On 24 September 1942, the establishment was raised to eight Mosquitoes and in December 1942 it was arranged for PAMPA flights to obtain meteorological information for the United States Air Force daylight operations as well as for night attacks by the Royal Air Force.

As the bombing offensive became heavier and more concentrated, there was need, in addition to the PAMPA flights whose primary role was to provide meteorological information for analysis by forecasters, for flights shortly before bombing raids to report on actual conditions in order to avoid wasted efforts, facilitate recalls and help in avoiding dangerous flying conditions such as heavy icing. These flights would observe, immediately before the take-off of the bomber force, the actual bombing conditions and the state of cloud at normal operating heights *en route*, in the target area or in an area from which the weather system was moving, and to signal these in code. It was considered that both forms of weather reconnaissance over enemy territory, for synoptic analysis and immediate operational use, would be most suitably executed by

[1] A.M. File S.4241. [2] A.M. File S.72851.

transferring the PAMPA flight, which had hitherto been under the direction of the Director of the Meteorological Office, to the Pathfinder Force within Bomber Command. Consequently, the Mosquito aircraft and crews of the PAMPA element of No. 521 Squadron, which had absorbed No. 1401 Flight, were transferred to Oakington in March 1943, to form No. 1409 Flight within No. 8 Group, Bomber Command. At the same time, the establishment was raised to ten Mosquito aircraft.[1]

The PAMPA flight continued to operate with the Pathfinder Force until the end of the war and contributed in no small measure to the success of the sustained bombing offensive.

Radio-Meteorological Flight

At the instigation of the Joint Meteorological Radio Propagation Sub-Committee, aircraft were used in an investigation of the conditions of anomalous propagation of radio-waves. After preliminary work during the summer of 1944, during which a suitable technique was worked out, six Oxford aircraft were allotted to form a Radio Meteorological Flight within the Technical Flying Unit at R.A.F. Station, Defford. In January 1945, the flight was sent to Brawdy to train for its special duties. The aircraft were equipped with spirit-in-glass strut Psychrometers, Mark V, and the operational task of the flight was to make detailed observations of dry and wet-bulb temperatures in a section of the atmosphere 1,500 feet high along a track crossing Cardigan Bay. This involved formation flying by up to four aircraft simultaneously, each at a different level. At certain intermediate points along the track, soundings were made to obtain temperature observations at height-intervals of every 100 feet. Whilst the meteorological observations were being obtained, simultaneous radio measurements were made at Ministry of Supply stations at each end of Cardigan Bay.

The detailed information provided by the Radio Meteorological Flight was of great assistance in elucidating the problems of anomalous propagation of radio waves.

In-flight Reports from Operational Aircraft

The procedure for obtaining weather reports from aircrews on their return to base was found to be inadequate in Coastal Command as individual sorties lasted many hours, and relieving aircraft had to be sent out before the return of those already on patrol or escort duty. In the early part of the war, before the regular meteorological reconnaissance flights were organised, forecasters at Coastal Command stations from which aircraft operated over the Atlantic, were faced with an area completely devoid of recent observations, or indeed, of observations of any kind; as a result, aircraft were sometimes dispatched when a report from an aircraft already in the operational area would have shown that weather conditions in the area were impracticable. The obvious solution was to obtain reports by wireless, but the matter was complicated by the necessity for wireless silence and other security considerations.

In order to obtain at least some information, local arrangements were made in No. 15 Group for aircraft operating west of 10° W. to send back weather reports whenever they broke wireless silence. At first, the Aircraft Landing Code (A.L.C.) was used for these reports, but it was not really satisfactory as it was designed for sending reports of surface conditions to aircraft about to

[1] A.M. File S.45354.

land and, in any case, it became obsolete towards the end of 1940.[1] A code form was then devised specifically for reports from aircraft, although it conformed as closely as possible to a similar code used by naval vessels to send weather reports when breaking wireless silence. The new code form continued in use in No. 15 Group until the final form described below was brought into use throughout Coastal Command.

The provision of a standard weather reporting code for use by all operational aircraft of Coastal Command was discussed by H.Q. Coastal Command and the Meteorological Office in May 1941. Two main problems had to be decided :—

(*a*) The code form to be used and the cyphering method to be used with it.

(*b*) The circumstances in which reports by wireless could be sent, so as to obtain the maximum number of reports without infringing security by revealing the position of convoys, patrol areas, etc.

The final code form evolved after consultations between the Air Ministry, Coastal Command H.Q. and Coastal Command Groups was known as the REOBS code. The main points were :—[2]

(*a*) Reports in the REOBS could be readily converted into a general code form, which had been evolved for all types of aircraft report, before being distributed by teleprinter.

(*b*) The code provided for two forms of report :—

  (i) An abbreviated report of cloud types, height and amount, general weather and visibility to be used when the weather suddenly deteriorated or improved.

  (ii) A full report which contained, in addition, information regarding wind speed and direction, state of the sea, surface pressure and temperature. The making of a full report entailed a descent to 50 feet above the surface of the sea.

As the transmission of the reports would involve breaking wireless silence and might affect the safety of the convoys, the Admiralty were consulted before the circumstances in which reports could be sent, were specified. The procedure suggested to the Admiralty was :—

(*a*) Aircraft (not on convoy duty) operating west of 10° W. should send a weather report as soon as they reached the limit of their patrol.

(*b*) Aircraft on anti-submarine escort duty west of 10° W., should, after making contact with their convoy, send a weather report at a distance of not less than 40 miles from the convoy.

(*c*) If at any time after making the reports as in (*a*) or (*b*) above, there was a rapid deterioration or improvement in the weather, the aircraft should send a further report, the transmission being at a distance of not less than 40 miles from the nearest convoy.

(*d*) Aircraft attacking specific targets should make a weather report only when other aircraft were being dispatched to attack, and there was enough time to benefit from the report.

(*e*) Weather reports would not be sent by aircraft on anti-submarine escort duties or if taking part in a specially defined, as opposed to a general, search.

[1] A.M. File S.67184.

[2] S.I.S. 17 and A.M. File S.67184.

The Admiralty agreed to these proposals with the exception of (*b*) for which they proposed to substitute an instruction that aircraft on anti-submarine escort duty should not report until they had completed their escort duty and were at least 40 miles from the convoy. As most aircraft remained on escort duty for six to eight hours, it was felt that the Admiralty suggestion would cause undue delay before a report was received, and a compromise was sought. It was finally decided to adopt the Admiralty suggestion as a general rule but that a special report should be sent whenever necessary to indicate that the weather was unfit for relief aircraft. These decisions were communicated to H.Q. Coastal Command in February 1942 and practical trials were carried out in the United Kingdom during the summer and autumn. As a result of these trials, it was decided to introduce the scheme in Nos. 15, 18 and 19 Groups and in Iceland.

The full procedure was introduced in the United Kingdom at the beginning of January 1943 and in Iceland on 15 February 1943. In the case of Iceland, the aircraft were only to report when more than 50 miles from the coast; they would otherwise all comply with the conditions of being west of 10° W. The definition of the circumstances in which reports should be sent was modified slightly by H.Q. Coastal Command to read as 'Aircraft operating west of 10° W., or Iceland based aircraft operating more than 50 miles from the coast, are to send weather reports by W/T with the following exceptions :—

(*a*) Aircraft on searches for a specially defined objective (as opposed to a general search or sweep) *are not to make W/T reports*.

(*b*) Aircraft on anti-aircraft escort or convoy escort may only make reports on completion of their duty, or when a report is needed to indicate that the weather is unfit for the relief aircraft. These reports should be made when the aircraft is not less than 40 miles distant from a convoy.

(*c*) Aircraft on strike duty are only to make weather reports when instructed to do so by Group H.Q.

These reports will be made as soon as the aircraft reaches the distant limit of its patrol '.

For some months, the REOB reports provided a most valuable source of information. They were rapidly exchanged between Iceland and the United Kingdom, and Coastal Command agreed to their distribution to a limited number of meteorological centres in Canada, Newfoundland, the United States and Bermuda which were principally concerned with Atlantic flying, viz. Dorval, Goose Bay, Gander, Presque Isle, Houlton, Washington and Bermuda. In view of the implications of the aircraft positions given in the reports, special security precautions were taken in their distribution. The original cyphered form of the reports as received from the aircraft was generally used in transmissions by wireless and for land-line transmissions in Canada and the United States, copies of the cypher being issued to authorised recipients. In the United Kingdom, the distribution by teleprinter was limited to those meteorological offices directly concerned (broadly, all Type 1 and Type 2 offices), and the position groups of the report were encyphered by means of special key groups which were changed daily.[1]

[1] A.M. File S.67184.

Unfortunately, REOB reports were plentiful for a few months only. In April 1943, H.Q. Coastal Command decided to reduce all types of wireless signals from aircraft to an absolute minimum and a number of new restrictions were introduced. The value of the REOB reports was recognised and at first the procedure was only modified to prohibit the routine transmission of the reports at the extreme limit of the patrol or at a distance of 40 miles from the convoy; instead, aircrews were instructed to send their reports not sooner than one hour and not later than one and a half hours after leaving the convoy or the extreme limit of the patrol. Under these regulations, a reasonable number of REOBs might still have been received, though subject to greater delays, but at the beginning of May, a more drastic Coastal Command Signals Security Instruction was issued which stated that weather reports from aircraft on convoy cover or reconnaissance in the Atlantic were only to be sent by the minimum number of carefully selected aircraft, compatible with the receipt of adequate meteorological information. These aircraft would be detailed by A.C., H.Q. These reports were not to be sent earlier than one and a half hours from leaving the convoy or ships under escort or the outer limit of the patrol.

In No. 19 Group, practically all aircraft were concentrated in limited areas and were forbidden to break wireless silence except for enemy reports, a veto which also involved No. 15 Group aircraft operating in the Bay of Biscay. At the same time, a considerable number of aircraft of No. 15 Group and aircraft from Iceland were used on the Iceland—Faeroes passage and did not, therefore, send reports. As a result, the flow of REOBs was reduced to a mere trickle, *e.g.*, six in a fortnight from No. 19 Group at the end of July 1943.[1] Arrangements had been made in July 1943 to introduce the REOB procedure at Coastal Command Operational Training Units and in April 1944 they were instructed to send reports at the turning point of all operational flight exercises, but this did not improve the position materially and very few REOBs were received during the last 18 months of the war.

It had been hoped that aircraft of the R.C.A.F. operating over the Western Atlantic would adopt the REOB procedure, and arrangements were well advanced by June 1943 for its introduction at Gander, Botwood, Tor Bay, Yarmouth, Sydney and Dartmouth, but the R.C.A.F. hesitated to introduce a procedure which had been virtually discontinued by Coastal Command, and the scheme was finally adandoned.[2]

Location of Sources of Atmospherics (SFERICS)[3]

Following earlier work by Marconi, Erskine Murray and others, R. A. Watson Watt and his collaborators, working under the auspices of the Radio Rearch Board, devised in 1923 a direction finder suitable for determining the bearings of individual atmospherics. The essential feature of the device is a cathode ray

[1] H.Q. Coastal Command issued instructions that a Beaufighter should be available on request to make meteorological observations but this was of little practical value as, apart from an aircraft not being available when required, Beaufighters could only operate during daylight hours in reasonably good weather, and there was necessarily a long delay between the request being made and the report being received. (A.M. File S.67184.)

[2] The arrangements made for in-flight reports from aircraft of Ferry/Transport Command are described in Chapter 11.

[3] A.M. File S.59685.

tube to the plates of which the North–South and East–West components of the radio wave created by the atmospheric discharge are applied after amplification through matched circuits. Frame aerials oriented accurately North–South and East–West pick up the corresponding components of the disturbance and the circuits are tuned to a very low frequency in order to obtain the maximum response and to avoid interference from commercial or other radio signals. With such an arrangement the oscillating disturbance originated by the atmospheric causes the central spot of light due to the electron beam of the cathode ray tube to be elongated momentarily into a line, the orientation of which can be read off from a scale of degrees marked on the screen. With correct positioning of the zero of the scale, the orientation of the trace on the screen can be made to be the same as the bearing of the atmospheric from the observing station (subject, however, to an ambiguity of 180 degrees, because deflections caused, for example, by disturbances due north of the station are indistinguishable from those due south of the station). The geographical position of the source can be determined by reading the bearings observed on the same atmospheric at two or more stations widely separated, plotting the bearing lines on a chart and finding their point of intersection.

This apparatus was brought into regular use by the Radio Research Board in 1925 and two stations, Slough and Cupar, were in operation in 1927. It was established that with a suitably disposed base line, sources could be located up to distances of the order of 1,000 or 1,500 miles, and that the disturbances located in this way were due to lightning.

With the loss of ordinary meteorological data from the Atlantic Ocean and most of the European continent on the outbreak of war, the information which Watson Watt's apparatus was capable of providing became very valuable. With the co-operation of the National Physical Laboratory, a station was established at the Central Forecasting Office at Dunstable in May 1940 on an experimental basis. A second station was set up at Leuchars in August 1940 and connected to Dunstable by a direct telephone line so that the operator at Dunstable could give verbal directions to ensure simultaneity of observations on individual atmospherics.

The results were encouraging, despite the limitations imposed by the existence of only one base line, and in October 1940 provision was made for the regular dissemination on the teleprinter network of reports giving the geographical positions of atmospheric sources. These reports were issued daily at 0800, 1300 and 2000 hours clock time and were preceded by the code word SFERIC. The frequency of reports was later greatly increased.

A third station was set up at St. Eval in August 1941 and the array of three stations thus created remained in operation until after the end of the war, when the geographic coverage was improved by the erection of a fourth station at Irvinestown in Northern Ireland.

The results furnished by the SFERIC service were particularly valuable in connection with offensive operations by Bomber Command, and in the location of fronts over ocean areas and enemy territory. Experience showed that lines of atmospheric sources tended to coincide with cold fronts or cold collusions, and the SFERIC observations thus gave valuable guidance in analysis when other information was lacking.

Ozone Measurements

For some years before the war, Dr. G. M. B. Dobson of Oxford had been studying ozone in the upper atmosphere, Results derived from a spectrophotometer designed by him had led to the establishment of the following principal facts :—

(*a*) The average amount of ozone, which occurs mainly at heights between 20 and 35 km. shows marked geographical variations, the amount increasing with distance from the equator.

(*b*) There is a seasonal variation, maximum values occurring in spring and minimum values in autumn.

(*c*) At any given place there are marked changes from day to day, the changes apparently being associated with changes of air mass over the observing station.

In view more particularly of consideration (*c*), it seemed possible that regular reports of ozone measurements from suitable stations would help in analysing the weather situation at the Central Forecasting Office. Arrangements were accordingly made early in 1940 for the transmission in code of reports for examination and study in relation to the synoptic situation. Investigations in this field carried out by Dobson and others before the war had yielded suggestive results but had not been pursued far enough to make possible the immediate use of ozone measurements in operational forecasting.

Arrangements were made to receive daily reports from observing stations at Eskdalemuir, Lerwick, Aberdeen and Oxford. Observations were normally taken between 1200 and 1300 hours G.M.T. Close contact was maintained with Dr. Dobson and a scientific officer who had been working with him at Oxford was posted to the Central Forecasting Office at Dunstable to carry on the investigation.

The results of this work did not prove to be valuable for routine forecasting purposes. Some correlation between ozone and the upper air parameters (particularly the temperature at 7 kilometres and the height of the tropopause) were revealed but the relationships were not close enough to be practically useful. The network of upper air observing stations and the technique of upper air analysis were being developed simultaneously with the work on ozone. It was found that the ozone measurements did not add materially to the upper air picture obtained from direct observations, and had no individual prognostic value. The project was therefore allowed to lapse.[1]

Reports from Neutrals and Allies

The sources of meteorological observations considered so far have been controlled by the Meteorological Office, but no efficient meteorological service can rely entirely on its own organisation. Modern forecasting technique is based on the receipt of reports from a wide area ; in forecasting for Europe, for example, reports are desirable from as far afield as U.S.A., Eastern Canada, Greenland, Spitzbergen, the Urals, Asia Minor and North Africa. The attempts made before the war to ensure the continued receipt of the observations required by the Meteorological Office have already been described. The reactions of the

[1] A.M. Files S.60017 and S.61428.

meteorological services of neutral countries to the outbreak of war varied. Eire, Turkey, Switzerland, Belgium, Holland and Russia suppressed their meteorological broadcasts and introduced meteorological security measures, whereas the United States, Iceland, Portugal and the Azores, Spain, Denmark and Norway continued to broadcast in clear until the end of October and then suppressed their reports.[1] The belligerents introduced full meteorological security at once.

Neutrals which Suppressed their Reports

Eire : The arrangements made just before the war for obtaining reports from Eire in exchange for certain meteorological data from this country were put into effect at once, and the exchange continued throughout the war years. At first, normal Post Office lines and cables were used, and the meteorological data from the United Kingdom were encyphered, although the data from Eire was sent in clear. The exchange was greatly speeded up by the installation of a teleprinter between the Central Forecasting Office and Collinstown in May 1941 and a private sounder line from Collinstown to Foynes in November 1941. The sounder-line was replaced later by a teleprinter and encyphering was dispensed with completely.

Turkey : On the outbreak of war, Turkey continued to broadcast meteorological data according to her peace-time programme, but the data were encyphered before transmission. The cypher used was, however, very elementary and the reports could be assumed to be available to any belligerent who could intercept the broadcasts. The Turkish Meteorological Service suffered from two other major defects from the viewpoint of the British Meteorological Service in the Middle East : the reports were not broadcast until 2¼ hours after the time of observation and very little upper air data was available.

In view of the uncertain political situation in the Middle East at the end of 1940, it was decided to post a meteorological officer to Ankara as an assistant Air Attaché to learn as much as possible of the Turkish meteorological organisation, in case it should be necessary to co-operate with that service, and to do what he could to remedy the defects mentioned above. For a number of reasons, he did not reach Ankara until June 1941 and he left again at the end of October. During that time much useful knowlegde was gained of the working of the Turkish service, but poor internal communications and lack of equipment made it difficult to improve the service. Arrangements made to supply pilot balloons and strut psychrometers (for making upper air temperature observations by aircraft) resulted in some increase in the amount of data available, but the delays in transmission continued until the end of the war.[2]

Attempts were made in the summer of 1941 to persuade the Turkish Meteorological Service to use a more secure cypher which the Air Ministry would provide. At first, success seemed possible, but in spite of renewed attempts at intervals during the next few years, no final agreement was reached and the service continued to use a series of insecure cyphers.

Low Countries and Scandinavia : In the case of the other neutrals who had suppressed their in-clear broadcasts, the Foreign Office representatives tried to obtain the reports in accordance with pre-war arrangements but in no case

[1] A.M. File S.54924.

[2] A.M. File S.61887.

did they succeed as the neutrals concerned felt that it would compromise their neutrality. In view of their situation on the German border, this attitude was not unexpected and alternative arrangements were put into effect in Belgium and Holland. Sweden decided to suppress her meteorological information and alternative arrangements were brought into force there. The invasion of Belgium, Holland, Denmark and Norway brought German security measures to those countries, but the arrangements made in Sweden were continued until the end of the war in Europe.

After the invasion of Norway, attempts were made to contact the Norwegian Meteorological Service and for a while at the end of April the British Consul and a naval meteorological officer succeeded in obtaining the reports of a number of stations from the collecting centre at Tromso and broadcasting them in cypher, but intercepting the broadcasts proved difficult. Cyphers were sent from this country for the use of the meteorological stations on Jan Mayen, Spitzbergen and Bear Island, but the project had to be abandoned.[1]

During the invasion of Belgium and Holland, efforts were made to arrange an exchange of data, first by teleprinter between Brussels and Paris and Brussels and Heston, and later by means of a mobile wireless station on the Belgian coast. Even after the cables between Holland and Belgium were cut, a few reports were received from Holland by transatlantic telephone, but communications ceased as the German armies overran the two countries.[2]

Neutrals which Continued to Broadcast their Reports

United States and Spain : No action was needed to obtain reports from the neutrals which continued to broadcast their meteorological data in clear, but every effort was made to devise means of denying them to the enemy. The possibility of jamming the reports had been considered before the war but had been rejected as impracticable, and action was confined to representations through diplomatic channels. It was decided that nothing could be done to prevent reports from the United States reaching the enemy, but steps were taken to minimise the risk of leakage of Canadian and Atlantic data, and to ensure the receipt of United States data in this country via Canada if direct interception failed. In the case of Spain, also, it was decided that no effective action could be taken and attention was concentrated on Iceland, Greenland and Portugal and the Azores. Not only did success seem possible in these countries, but they were far the most important from the point of view of European forecasting. As long as their reports were available to the enemy, they represented major leakages in the meteorological blockade.

Iceland : The British Consul was instructed on 4 September 1939 to make strong representations to the Icelandic Government to stop all wireless broadcasts of meteorological reports and forecasts referring to Iceland and, instead, to send the Icelandic reports to London by cable as was the practice when the wireless station could not transmit.[3] The Icelandic Government intimated their willingness to suppress the wireless broadcasts, apart from local forecasts for the fishing fleets, but would not agree to cable the reports.

[1] A.M. File S.59739/I.

[2] A.M. File S.38063.

[3] The costs of the meteorological synoptic broadcasts from Iceland were met by the International Meteorological Organisation, and a clause in the contract stipulated the transmission of the reports by cable in the event of wireless failure. (A.M. File S.59739/I.)

It was agreed that it would be preferable to accept the Icelandic Government's offer and to make alternative arrangements for obtaining reports from Iceland, rather than allow the broadcasts to continue in clear, but the existence of various channels of communication between Germany and the German Consul in Reykjavik complicated the situation. It was suggested to the Icelandic Government that they reserve for their own use the official channels (a radio telephone link with Denmark and wireless links with the United States and Greenland), but the problem was further complicated by rumours of a secret short-wave transmitter in the German consulate. The Icelandic Government delayed their reply while trying to detect the short-wave transmitter until they were pressed for a decision in January 1940. Their reply showed that they were most unwilling to reserve the communication channels for their own use and they asked the British Government to reconsider their request.

At that juncture the cable between Iceland and the United Kingdom broke and remained out of action for two months until naval escort could be provided for the cable ship. As the cable had been an essential part of the plans to obtain the official Icelandic reports or other reports, the question was dropped for a time. It was re-opened at the beginning of March and it was decided then to press again for the suppression of all meteorological broadcasts even if the Icelandic Government would not reserve the other channels of communication for their own use, although every effort was to be made to persuade them to do so.

The position was fully discussed with the New British Consul who was being posted to Iceland but before he reached Iceland the Germans invaded Denmark and it was feared for a time that the tables might be turned. As the attitude of the Icelandic Government became clear, however, the Foreign Office decided they could insist, if necessary, on our proposals being accepted. The Consul was instructed accordingly and the Icelandic Government suppressed the wireless broadcast and the radio telephone link from 15 April. The only channel of communication left open to the Germans was a wireless link via the United States, and a considerable delay was imposed on all messages on this route.

Although there were a few troubles at first, the arrangements for receiving the reports in the United Kingdom worked fairly well. They were normally sent by cable, but if that channel broke down, they were sent by wireless in a meteorological cypher which had been supplied to the Consul. The main faults were delays in dispatch and transmission, and steps were taken to rectify these when a meteorological officer landed with the British forces in May. The Icelandic Meteorological Service proved willing to co-operate, and from then onwards, it was developed to provide the basic reporting network on the island to meet the need of the Allies generally and of the forces in Iceland in particular. The forecasting work was done by the R.A.F. Meteorological section, and the transmission of data by wireless and cable outside the island came under the auspicies of the British and American Services.

Greenland : The meteorological stations in Greenland, with two exceptions, were staffed by Danes, and the reports were transmitted to Copenhagen via a collecting centre at Julianehaab. They were, therefore, available in the Danish collective broadcasts until Denmark was invaded. The two exceptions were

Norwegian stations, Myggbukta and Targilsbu, on the east coast, which relayed their reports to Norway via Jan Mayen, the reports then being broadcast with the Norwegian collectives. After the occupation of Denmark and Norway, the Danish collecting centre at Julianehaab continued to report to Copenhagen ; the position regarding the two Norwegian stations was obscure. Unsuccessful attempts were made to intercept the various transmissions[1] so it was decided to clarify the situation and obtain the reports for the exclusive use of the Allies if possible.

The Norwegian Government agreed to send a Norwegian relief ship and escort in the summer of 1940 to investigate the situation on the east coast. The expedition captured a German party which had been landed, and in view of the possibility of other German attempts to dominate the east coast, the two Norwegian stations were dismantled and the operators removed. Cyphers had been supplied to the expedition in the hope that the stations might report to Iceland, but it was decided that this course was impracticable.[2]

In the case of the Danish stations, the Canadian Government undertook negotiations with the Governor of Greenland, as it was hoped that this would avoid a number of political difficulties, particularly *vis-à-vis* the United States. The Canadian Government had been unable to obtain a satisfactory reply from the Governor of Greenland by September 1940, and the United States, who had been kept informed, agreed to take over the negotiations. This change had the desired effect as the Governor apparently considered that any changes in procedure introduced at the request of the United States would not compromise Greenland's neutrality. As a first step, he was persuaded to stop all broadcasts of weather reports from Greenland from 17 September. This was done at the suggestion of the Canadian authorities in view of the value to the Germans of reports from Greenland in forecasting suitable weather for the impending invasion of England.

Negotiations to obtain the reports for the United States, Canada and the United Kingdom continued until December 1940 when arrangements were completed for the transmission of the reports in cypher to the United States. Reports were received very irregularly from that time, but there were many communication difficulties and the number of stages involved before the reports reached the United Kingdom caused inordinate delays. The Danish stations on the east coast presented a particularly difficult problem. A Norwegian ship attempted to supply them with cyphers in November, but by then the ice had closed in and they were unapproachable. As an overland journey was impossible, it was decided to attempt to drop cyphers from the air to the operators at Angmagzalik and Scoresby Sund, and to use those two stations only. As the Governor felt he could not issue instructions to the stations in clear by wireless, a simple administrative cypher had to be provided as well as the meteorological cyphers. A Sunderland aircraft flying from Iceland was to drop the cyphers but the distances involved made it necessary to wait until March for enough daylight, and the Governor withheld his final approval of the flight until April. By then, there were reports of German aircraft flying over the

[1] The proximity of the magnetic pole makes wireless communication with Greenland difficult and erratic, and even after the American Forces had taken over the stations, communications were difficult.

[2] A.M. File S.62711.

settlements and a fear that German parachutists might be in possession led to a further postponement. The cyphers were not finally dropped until the end of June and reports were received from the beginning of August.

Meanwhile, the United States forces had occupied Greenland, for whose meteorological service they assumed responsibility. They established their own communication network and opened new stations, but although more station reports were now available, they were received in this country irregularly and after great delay. For the remainder of the war, vigorous efforts were made, and many expedients tried, to overcome these defects, but they were only partly successful. The two main causes of delay were the natural difficulty of wireless communication in the Greenland area and the United States practice of distributing the reports on their network as point-to-point messages and not as fixed time broadcasts which is the normal meteorological practice. These combined to make direct interception in this country almost impossible, and the reports had to be received either via Iceland or Canada. The reports could be intercepted in Iceland fairly regularly, but they had then to be transmitted to the United Kingdom. Various ways of doing this were tried—adding them to the next routine Iceland transmission, sending a selection by immediate cable, or passing them via Prestwick on the high speed wireless auto-channel between Reykjavik and Prestwick—but the number of re-transmissions involved still caused delay. The route via Canada suffered from the same defects, as there were a number of internal links in Canada before the reports could be sent from Newfoundland or Goose Bay to Prestwick.

Jan Mayen and the Faeroes : For a time after the evacuation of Norway, it was hoped to maintain the Norwegian meteorological station on Jan Mayen for the benefit of the Allies, but when the problem was examined in more detail, the practical difficulties were found to be so great that it would be better to close the station. The Norwegian Government agreed, and in September 1940 one of their ships visited the island, destroyed the station and removed the staff. It was later decided to re-open the station with Norwegian staff available in Iceland, and the new station began to function early in 1941. It continued to send surface reports and later radio-sonde reports until the end of the war.

It was comparatively easy to make suitable arrangements regarding the meteorological reports from the Faeroes. Before Denmark fell, these reports were sent to Copenhagen by cable which passed through the United Kingdom. By a pre-war agreement, drop-copies of the cables were taken to Aberdeen and forwarded to the Central Forecasting Office, so that it was only necessary to impose a suitable delay on the onward transmission of the reports to Denmark. After the occupation of Denmark, arrangements were made through the British Consul for the Danish observer to continue sending the reports to the United Kingdom until the meteorological station, established for the use of the R.A.F., took over the reporting duties.

Portugal and the Azores : Reports from the Azores are second in importance only to those from Iceland for forecasting in Europe, and their value in war-time was increased by the sparseness of other data from the Atlantic. When it became clear that the Portuguese Government did not intend to suppress the reports, it was decided to try to persuade them to do so. Besides being broadcast

from the Azores and repeated in the Lisbon broadcasts, the reports were sent to this country by cable in accordance with a long standing agreement. This arrangement was not widely known and it was hoped that by keeping it in the background, the cabled reports would be continued if the wireless broadcasts were stopped.[1] The Portuguese Government were asked at the beginning of January 1940 to suppress all broadcasting of the Azores by wireless, as they were of definite help to the Germans in their piratical operations at sea, and the suppression of the wireless issues was in itself a perfectly neutral act. The Portuguese replied, in mid-February, that they would have to face the following difficulties if they suppressed the reports : they would be unable to provide the meteorological information required for transatlantic flying ; the suppression of the wireless issues would be ineffective because the information thus suppressed might be broadcast by other countries and by American ships in the Atlantic ; Portugal would be failing in her neutrality and in particular in her co-operation with the United States.

Although effective answers were supplied to these objections, the Portuguese Government still hesitated as they apparently feared that the United States would transfer the base of their transatlantic air routes elsewhere if the British proposals were put into effect. It became clear that the help of the United States Government would have to be enlisted if progress was to be made, and in June the British Air Attaché in Washington was instructed to try to secure United States support on the understanding that the reports would be sent to them confidentially by cable. The United States Weather Bureau and Pan-American Airways gave an assurance at the end of August that they would raise no strong objection to the suppression of the Azores reports, but as a number of delicate questions were then under discussion with the Portuguese Government, the British Ambassador decided to postpone a further approach concerning the Azores reports until the situation was clearer.

Meanwhile, the U.S. Civil Aeronautics Society complained to the American Embassy in this country that negotiations which they were undertaking with the Portuguese, regarding point-to-point communication between the United States and the Azores were being handicapped by Portugal's unwillingness to include meteorological reports in the agreements because of the British efforts to secure their suppression. There had clearly been a lack of co-ordination between the United States authorities and, when the American Embassy approached the Foreign Office in November, 1940, it was necessary to recapitulate the whole history of the negotiations. It was still hoped to enlist the support of the United States but 1941 passed without their representatives in Lisbon receiving the necessary instructions.

After entering the war in December 1941, the United States authorities were again approached and they agreed to support our representations, but in March 1942, the British Embassy in Lisbon pointed out that the Germans would probably retaliate by having the Spanish reports suppressed. The matter was, therefore, reconsidered, and as it was felt that the Portuguese data would almost certainly leak through to Germany even if the wireless issues were suppressed, it was decided that the risk of having the Spanish reports suppressed was not justified by merely delaying the receipt of the Azores reports in Germany. The British Ambassador in Lisbon was, therefore

[1] A.M. File S.60013.

instructed to discontinue the negotiations, and the Azores continued to be broadcast in clear until the British Forces landed in October 1943. As the question of meteorological reports had not been included in the preliminary arrangements with the Portuguese, a number of difficulties arose after the landings and were not finally cleared for some time.

Allied Countries

France : The arrangement for installing a meteorological teleprinter between London and Paris and for exchanging data in war-time worked, on the whole, smoothly between London and Paris, but the supply of data from Paris to the meteorological stations with the Expeditionary Force was somewhat erratic, mainly because of technical signalling difficulties, the difference between British and French teleprinters and the type of land-line available. The exchange of data between the British and French services in the Mediterranean and Middle East was less satisfactory. The pre-war agreement that Paris would send to London the reports normally collected there, and vice versa, meant, in practice, that reports from Tunis, for example, were cabled to Paris, then teleprinted to London and finally cabled again to Malta, Gibraltar and Heliopolis, a circuitous route involving great delays. French reception of British reports from the areas in question was greatly speeded up when the Eastern Mediterranean was derestricted in mid-September 1939, but it was not until March 1940 that in clear broadcasts from Syria were issued on a wavelength which could be received by the British meteorological sources in the Middle East ; and the Algerian and Tunisian reports still followed the route mentioned above. In October and December 1939, it was suggested to the French Meteorological Office that the British Consul in Tunis, or the local meteorological headquarters, should cable the reports direct to the meteorological offices in Heliopolis, Malta and Gibraltar. A French counter-suggestion that the reports should be issued in clear and an apparent misunderstanding regarding the responsibility for taking action about the direct cables led to delay, and the route via Paris and London was still being used when the problem was resolved, as far as Tunis was concerned, by the French decision in January 1940 to issue the Tunis reports in clear. The reports from Algeria and Morocco were, however, still received by the long land-line route and were consequently received only after great delay.

When it became inevitable, towards the end of May 1940, that the Mediterranean would become an active theatre of war, the French Meteorological Service was asked to consider means of improving the exchange. They agreed to broadcast regional collective messages from Tunis, Algiers and Morocco in the British Confidential Meteorological Code and to broadcast more general collectives in the same code from Tunis and Heliopolis. The regional transmissions from Algiers and Morocco were begun in the first few days of June, but all exchanges stopped when France fell.

Poland : The Franco-British Meteorological Conference in Paris in August 1939 had agreed upon a means of exchanging meteorological information with Poland. It was intended that the Polish service should intercept the British Fleet Synoptics and pass them to the British Embassy for decyphering, and that the British Embassy should obtain the Polish reports and transmit them by cable to London. Details of the Fleet Synoptic Messages were signalled to Warsaw on 28 August, but a reply was received on 31 August requesting

reports four times a day at the main observing hours.[1] The Polish service offered in exchange reports from a dozen Polish stations four times a day. Arrangements were made to meet the Polish request and transmissions of the reports from a Post Office wireless station to Warsaw began on 5 September. The messages were decyphered in the British Embassy and passed on to the Polish Meteorological Service. Reports from Poland were received for a few days but they ceased on 5 September. The transmission of British reports to Poland continued until 18 September when the Polish Government left the country.

The United States : During the first year of the war, the main source of meteorological data from the United States was the high-powered wireless station at Arlington (NAA) which broadcast a selection of reports several times a day. Reception of these broadcasts was sometimes difficult but they provided a fairly adequate source of data until the development of intensive transatlantic flying. Early in 1941, the power of the Arlington broadcasts was reduced, apparently a step intended to aid Britain by making the reception of the reports in Germany more difficult but one which proved to be of doubtful value as the reports had to be retransmitted to this country from Newfoundland and were consequently subject to delay. Later, a second source of data from the United States was provided by a new series of broadcasts from a Civil Aeronautics Authority station at Sayville (WSY), but the broadcasts ceased in October 1941 and were replaced by point-to-point traffic with aerials directed on Newfoundland. Neither of these sources provided all the data needed in this country in connection with the transatlantic flying programme which had developed, but as the United States were still neutral, little could be done apart from supplementing the data obtained direct from the United States by data obtained through Canada and Newfoundland.

When the United States entered the war in December 1941, the in-clear transmissions from Arlington and Sayville ceased. As attempts to receive the new cypher transmissions from Arlington had little success, arrangements were made to transmit a selection of United States reports from Toronto to Prestwick in a special pad cypher until a more satisfactory scheme could be worked out. A provisional statement of British requirements was communicated to the U.S. Naval Air Attaché, who was acting as meteorological liaison officer in London, at the end of December. The data required from Canada and the United States were dealt with together, and were stated to be :—

(*a*) Reports from a network of about 80 stations distributed over the United States and Canada with greater density in the east than in the west, and a good representation of eastern coastal stations.

(*b*) Complete observations from about six radio-sonde stations.

(*c*) Observations for heights of 5,000, 10,000, 15,000 and 20,000 feet from about six pilot balloon stations.

(*d*) Ships' reports in the western North Atlantic.

(*e*) An analysis covering North America and the adjacent waters. The analysis to be complete and to indicate the anticipated motion of fronts as well as the intensity of associated fronts and weather.

(*f*) The isobars at 5 kms. or the isopleths of the 500 mb. surface.

[1] At that time, Fleet Synoptic Messages were only issued twice daily.

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A meeting on 2 February 1942, at which the Naval Meteorological Service was represented, considered more fully the British requirements for naval operations, transatlantic flying and forecasting in the United Kingdom. On the question of general policy, it was agreed that the United States should be asked to make basic synoptic broadcasts for North America using a frequency and power which would ensure reception in this country, and that the additional data required by Prestwick for transatlantic flying should be obtained on the Newfoundland—Prestwick point-to-point system. A statement of the desired contents of the broadcasts was drawn up on this basis and communicated to the United States and Canada.[1] A new statement drawn up in December 1942 increased the number of station reports to about 150 at 0100 and 1300 G.M.T., by omitting the upper wind reports and by increasing the number of radio-sonde reports to about 20 (but suggesting an abbreviated form).

It was suggested that eventually, high speed transmission from Sayville (WSY) should be made, but as the arrangements for this were likely to take some time, it was agreed with the Canadian Meteorological Service that the new meteorological point-to-point wireless channel, which was being established between Dorval and Prestwick to handle meteorological traffic for transatlantic flying, should be used as an interim measure. Although the Dorval—Prestwick channel ensured this receipt of the data at Prestwick, it was not wholly satisfactory as delays of up to seven hours occurred and the data had then to be passed to the Central Forecasting Office for retransmission. Strenuous efforts were made to reduce the delay, and the use of cable for routine synoptic reports was suggested as a means of relieving the congestion on the wireless channel.

The negotiations to obtain the basic synoptic broadcast proved to be extremely difficult. The United States authorities had to be convinced that there was a good case for the special synoptic broadcasts, and at the same time it was essential to ensure the continued receipt of the data by other means until the broadcasts were established. The United States Services were naturally concentrating on the requirements of the north-east ferry route, and the WSY programme was designed to meet the needs of the United States Weather services on that route. The broadcasts from WSY consisted mainly of repetitions of other regional broadcasts, transmitted at a speed which would ensure accurate reception in the difficult wireless conditions which prevailed along that route, and the U.S.A.A.F., who were responsible for the broadcasts, found it difficult to appreciate the wider importance of the reports and were unwilling to change their existing schedules. Differences in practice added to the difficulties due to differences in viewpoint. For example, the United States services pointed out, in reply to the British request for the isopleths of the 500 mb. surface, that the calculation of these isopleths was not standard American practice and would involve an entirely new process of computation. They offered to supply raw data instead but finally agreed to prepare the isopleth messages when they were told that the isopleths would represent the interpretation by the American experts of all the available data, not only upper air temperatures but upper winds, surface synoptic distribution, mountain and cloud observations, etc. The 500 mb. isopleths were duly transmitted as separate messages but general broadcasts of data in the form specified in the

[1] A.M. File S.77452.

British request were not made as the United States authorities considered that the extended WSY schedule, introduced about then, met most of the requirements. They did, indeed, contain the data required, but they were so dispersed through a mass of other data that 3–3½ hours reception time daily had to be used to obtain the reports required; the introduction of a special high speed transmission at 125 words a minute would have reduced the listening time to ½ hour four times daily.

It had been hoped to enlist the support of the Canadian Meteorological Service in these negotiations, but this also proved difficult as that service was concentrating on the transatlantic flying aspect and was most reluctant to advocate a change which would disturb the exchange of synoptic data which had been developed between Dorval and Prestwick.

The question of special high-speed transmissions was reopened in July 1944, but without success, and the normal broadcasts from WSY remained the source of data from the United States until the end of the war.

Other Sources of Meteorological Information

In addition to the sources of meteorological information already mentioned, a number of organisations supplemented the main network of reports. These supplementary sources are described briefly below.

Thunderstorm Reports from Observer Corps

The importance to Balloon Barrages of adequate thunderstorm warnings led to selected Royal Observer Corps stations reporting their occurrence in order to supplement reports from stations staffed by the Meteorological Office. On 10 March 1940, 45 Observer Corps posts began these reports which the Senior Meteorological Officers of the Fighter Groups received through the Observer Corps Group Liaison Officer. Group Meteorological Officers passed the reports to the Balloon Barrages they served and to the Central Forecasting Office for broadcasting on the meteorological teleprinter network.

Reports from Passenger Steamers and Lightships

Telegraphic weather reports from cross-Channel ships ceased when war broke out. Inquiries regarding their recommencement were made late in the autumn of 1939, and coded reports of sea water temperature midway along the Belfast—Heysham and Kingstown—Holyhead crossings were sent from 19 August 1941 to the Central Forecasting Office on the ship's arrival at the home port. Reports were later made on the Larne—Stranraer route and, by the end of the war, from 13 positions off the British coasts. The Sunk, Tongue and Knock Lightships in the North Sea supplied similar data, with wind, weather, state of sea and visibility, from July 1942.[1]

Reports of Cloud Height from Searchlight Posts

The A.O.C.-in-C. Fighter Command, was asked in November 1940 whether anti-aircraft searchlights might determine cloud height each night and pass the information to meteorological officers at Fighter Sector Stations. It was arranged for cloud heights to be thus computed at 30 searchlight sites four

[1] S.D.I. 19.

times nightly. From June 1941, the heights so obtained were reported through Fighter Sector Stations to the Central Forecasting Office and broadcast on the meteorological teleprinter network.[1]

Routine Reports from Observer Corps Posts

From June 1941, 50 Observer Corps posts made regular observations of weather, visibility and cloud height and amount eight times daily. Another 80 posts were available for occasional reports when required. The reports were valuable, as most of the posts were in remote areas, and were broadcast to all stations on the meteorological teleprinter network.[2]

Cloud Reports from Balloon Barrages

Until 1942, information on the vertical thickness of fog and lower cloud layers was obtained from aircrews who happened to fly through or above fog or cloud. The Air Staff were then advised that this information could be obtained regularly by rigging below a barrage balloon a Fine-Gap Cloud Indicator, which had been developed at Cardington. Cloud indicators were issued to 30 Balloon Barrages and reports began in March 1942.[3]

[1] S.D.I. 51. [2] S.D.I. 54. [3] S.D.I. 74.

CHAPTER 28

COMMUNICATIONS

Meteorological Teleprinter Network in the United Kingdom

Development of a Teleprinter Network[1]

The success of any weather forecasting service depends very largely upon the prompt and accurate receipt of frequent reports from a large number of well-distributed observing stations. Until September 1937, reports had been collected and disseminated entirely by live telegraphy and wireless telegraphy, but the Meteorological Office then began to use teleprinters for communication between meteorological offices in this country. The advantages of teleprinter operation were realised, and a ' Meteorological Teleprinter Network ' reserved exclusively for meteorological traffic was rapidly developed during the following two years. In March 1939, facilities were installed for automatic broadcast transmissions to all offices at a speed of 55–60 groups per minute. By the summer of 1939 a fairly large proportion (43) of the airfields had meteorological offices which were sending in reports to the Meteorological Office in London by teleprinter and were receiving information by the same means. A number of these were connected to a neighbouring station and not directly to Headquarters.

The great advantage of teleprinter working in the event of war was clear; compared with W/T it made it far more difficult for an enemy to obtain information and, also, it maintained the peace-time speed of communication by avoiding the use of cyphers. With the expansion of the system, accommodation for the increasing number of teleprinters at the Meteorological Office presented a problem which, coupled with the desirability of transferring the ' nerve centre ' for weather information away from London, led to the planning of a war-time communications H.Q. at Dunstable. Pending the completion of Dunstable, a temporary H.Q. at Birmingham was occupied on 27 August 1939 by the Central Forecasting Office (ETA). There were 28 direct lines to H.Q. at that time. There was also a line to the French Meteorological H.Q. in Paris (ONM). Other lines were gradually installed, including one to G.H.Q., B.E.F. on 12 November 1939.

In accordance with pre-war policy, the stations on the teleprinter network were divided into groups. A direct line connected ETA to the main stations from which lines radiated through a switchboard to other stations in the group. This arrangement saved long lines direct to ETA and enabled the main station or collecting centre to communicate with other stations of the group. By simple key manipulation, the broadcast from ETA could be passed on to the satellite stations or the teleprinters could be used for intercommunication between the collecting centre and its satellites. Wherever possible, the arrangement of collecting centres and their satellites or tails corresponded to the R.A.F. grouping of stations under Group H.Q., *i.e.* the teleprinter collecting

[1] A.M. File S.46564.

centre was the Type 1 meteorological office at a Group H.Q. and the tails served the meteorological offices on the stations of that Group.[1] This facilitated communication and co-ordination within the Groups, but for geographical and other reasons it was not always practical; for example, there were no meteorological offices at Flying Training Command Group H.Q. and in the case of some outlying Coastal Command stations, direct communication to their Group H.Q. was impracticable. In such cases, the stations were connected to the collecting centre to which land-line communication could most conveniently be provided. The first group switchboards were installed at Wyton, Hucknall, Grantham and Mildenhall in June 1939. Others were installed during the following months so that by January 1940 all existing meteorological offices at R.A.F. Group H.Q. possessed a switchboard linking them with satellite stations.

Direct communication was established in January 1940 with the telegraph room of the Birmingham Head Post Office, via Telex circuit, for the disposal of inland and overseas messages by telegram. The Fleet Synoptic Messages which were, at that time, prepared and cyphered at ETA for the Naval Meteorological Branch, were teleprinted to the Admiralty in London on a direct line, for broadcasting by wireless. These were lengthy messages requiring very careful scrutiny. To cover possible power supply breakdown, a diesel engine was provided and periodic tests instituted to ensure the working of this alternative supply in case of emergency.

The move to Dunstable was made on 4 February 1940. At 1600 hours on that day, all lines were switched from Birmingham, and reception and broadcast transmission was performed at Dunstable without any appreciable break or loss of data. Shortly after the move to Dunstable, reperforators were fitted to the reception circuits of all collecting centres which sent in collective hourly reports to ETA. This greatly eased the retransmission of British data to all stations as, previously, the tape for the automatic transmitter had to be punched by hand. To avoid interference with wireless reception, suppressors were fitted to all teleprinter apparatus early in 1940.

The evacuation from France in May 1940 resulted in the cessation of direct communication with ONM Paris and G.H.Q., B.E.F., but the network in the United Kingdom continued to expand rapidly. In May 1941, teleprinter communication was established with the Central Telegraph Office, Dublin, and in November 1941, the Dublin terminal of this circuit was transferred to the office of the Eire Meteorological Service on Collinstown airport.

Towards the end of 1941, the continued increase in the amount of material to be handled made it necessary to duplicate all direct lines from ETA to Group and Command H.Q. in order that the overflow from the main broadcast could be made available to these centres without material delay. These lines were installed and working by December 1941.[2]

The first U.S.A.A.F. Command H.Q. in the United Kingdom (' Wide Wing ') was opened in 1942. Two teleprinter lines were provided to it on 10 August, to be followed by circuits to ' Pinetrees,' H.Q. U.S. Bomber Command, to ' Ajax,' H.Q. U.S. Fighter Command, and to the individual U.S.A.A.F. Wings

[1] It would have been impracticable to follow the complete R.A.F. chain of Station–Group–Command as this would have created an unworkable bottleneck in the collection of reports at Command level. A.M. File S.64786.

[2] A.M. File S.46564.

and stations on the same scale and plan as their R.A.F. counterparts. The new commitments necessitated a reorganisation of the teleprinter facilities, and, to meet these and unforeseen commitments, two 100-line broadcast boards were installed at ETA in October 1942. Fortunately, British teleprinters and American tele-types worked well on the same circuits. The opening of stations manned by the U.S.A.A.F. was mainly responsible for the number of stations on the meteorological teleprinter network increasing from 237 at the end of 1942 to 445 by the end of 1943, an increase of 88 per cent.

Teleprinter communication was re-established with the continent in June 1944, and teleprinter working with H.Q. 2nd Tactical Air Force was established early in August. Communication was established with Paris ONM on 10 December 1944, with Brussels on 13 October 1945 and with Utrecht on 15 October 1945. In January 1945, a separate 10-line switchboard was installed at ETA, and all existing overseas teleprinter lines were terminated on this board, other overseas circuits being added as they were installed. First and second channel material was distributed direct to the French, Belgian and Dutch national meteorological services in Paris, Brussels and Utrecht respectively, to H.Q. British Forces in Occupied Germany at Bad Eilsen, and to the U.S.A.A.F. H.Q. at Orly Field near Paris. Sixty stations were joined direct to ETA at that time, most of them having second channel facilities.

As bombing raids on targets in Germany became intensified in the later stages of the war, H.Q. Bomber Command needed a third teleprinter channel direct from ETA to the Command meteoroloical office, over which could be sent ' advance ' material including much upper air information which was vital to their requirements. The line was installed in September 1944 and was soon afterwards extended to U.S. Bomber H.Q. at ' Pinetrees.' Facilities for automatic transmission were provided to enable ' taped ' material to be used and so avoid delays.

The problem of sending direct to ETA the rather long messages containing observations from meteorological reconnaissance flights and radio-sonde reports was solved by introducing facilities for ' Duplex ' working on certain 2nd Channel teleprinter channels, thus allowing simultaneous reception and transmission on the same line. Facilities for Duplex working were introduced at Pitreavie on 16 January 1945, at Gloucester on 1 July 1945 and at Liverpool on 1 August 1945. Huntington, Prestwick and Plymouth were given duplex facilities later. This made it unnecessary for these centres to wait for ' break ' periods in the ETA braoadcast; simultaneous sending and receiving made it possible to transmit the reports to ETA immediately they were available. Duplex facilities were also provided on certain other channels which had to carry heavy traffic in both directions. All lines to the continent were made to work duplex when they were installed. A duplex circuit which was installed between ETA and Prestwick in January 1944 for the transmission of N. Atlantic data, formed part of a small broadcast network connecting Prestwick with the main United Kingdom stations, including transatlantic terminals, which required to compile complete synoptic charts of the whole of the N. Atlantic; recipients of this broadcast included ETA, Transport Command, Gloucester, No. 15 Group (Liverpool), No. 19 Group (Plymouth) and terminal or diversion airfields at St. Mawgan, Valley and Nutt's Corner.

At the end of the war, there were 552 recipients of the 1st Channel ETA broadcast including overseas recipients.

Teleprinter Broadcast Schedules

British stations began to broadcast hourly reports throughout the 24 hours on 3 September 1939. These hourly reports were in semi-plain language, *e.g.* LYMP C 4,000 yards 1,000 feet 9/10 WSW 2, Bar 1016, and were supplemented at synoptic hours by the broadcast of the reports from all full synoptic stations in the international code.

Checks on the reception and broadcast of weather reports in semi-plain language showed in the summer of 1940 that the frequent change over from letters to figures and vice versa in teleprinting was causing discrepancies. Accordingly, to reduce errors thus caused, the text of each report was transmitted in figure code from 8 August 1940. At the same time, it was decided to broadcast the station reports in a fixed order so that any particular station would be found in the same position in the broadcast at all hours at which it reported. As a further aid to picking out an individual report, each report was prefixed by a three-letter group. Certain additions were made to the code to give extra information. The teleprinting procedure was arranged so that each full synoptic station would have a line to itself, with non-synoptic stations two on a line. This layout gave a more orderly appearance to the broadcast and materially helped to locate stations on the teleprinter copy.

From 1 October 1940, collective reports from collecting centres were prepared in two sections, the first containing station surface reports and the second containing upper air data and miscellaneous reports including late reports and Beaufort letters. The full name of the collecting centre, followed by the hour of observation in clock time, preceded Section 1 of each collective. The transmission of collective reports from collecting centres to ETA was timed to be completed by ten minutes past each hour, and the collective messages were then re-broadcast by ETA on an automatic transmitter, part one of the broadcast containing Section 1 of the collectives and part two containing Section 2.

Nine months later, on 10 July 1941, arrangements for the operation of the meteorological teleprinter network were revised to effect a quicker and more uniform issue of essential reports. The main features of the changes were :—

(*a*) Arrangements for the synchronisation of time between ETA and collecting centres and the introduction of a detailed timetable showing fixed times for the broadcast of regular forecasts, analyses, etc.

(*b*) Reduction of the number of full synoptic reporting stations to a selection of about 90.[1]

(*c*) Complete headings giving data and time of observations were confined to a selection of four collecting centres while the remaining centres inserted the name only.

(*d*) Omission of late reports at non-synoptic hours or late abbreviated reports at synoptic hours unless they contained some special phenomena.

By this means, the broadcasting of all surface reports was completed by about 30 minutes past each hour.

[1] Hitherto, there had been no definite policy in deciding whether a new station should make full reports or abbreviated reports.

The schedules of forecasts, analyses, etc., broadcast from ETA were revised in February 1942 to include additional information including a composite bulletin four times daily which consisted of a Baratic, Prebaratic,[1] Baranal and Aviation Forecast.

As the number of reporting stations throughout the country continued to increase, it became ever more difficult to broadcast all the reports received at ETA each hour. The resulting accumulation of data for broadcasting led to delays and it was decided in July 1942 to reduce the reports from a number of stations to a fitness number only. About 40 stations in localities already well represented were treated in this way. The weather fitness numbers from these stations were included in sequence at the end of Section 1 of the group collective, *e.g.* on the Exning Section 1 Collective, the fitness figures from Oakington, Feltwell and Waterbeach were added as : OAKFLTWBH 865.

When changes in code came into effect on 1 December 1943, certain changes were also made in the reporting and distributing routine. The main alterations were :—

(*a*) Reports from ' full synoptic stations ' were issued in full code at all hours.

(*b*) Reports from other stations, ' abbreviating reporting stations,' were reduced to three groups of figures, giving heights and amounts and form of cloud, visibility and weather, but omitting wind and past weather.

(*c*) Station index letters were abolished.

(*d*) The reporting of fitness numbers only for some stations was cancelled.

A revised form of collective message to be sent by the collecting centres to ETA was also evolved. This consisted of three sections :—

Section 1 : standard surface reports to be broadcast ;
Section 2 : other reports to be broadcast ; and
Section 3 : reports not to be broadcast.

Section 1 contained reports from full synoptic stations, one station to each line, followed by reports from abbreviated reporting stations, two stations to each line. Section 2 contained pilot balloon ascents, nephoscope reports and surface reports too late for inclusion in Section 1. Section 3 contained rainfall and sunshine groups, Beaufort letters and any additional information, provided it did not entail the message extending beyond the period allotted for transmission to ETA. At that time, collectives were received from 28 centres ; these were broadcast in fixed order and five of these, evenly spaced, were chosen to give the name, date and time (clock-time) at the beginning of the collective, *e.g.* NEWCASTLE JAN 1 1944 1200

while the remaining centres gave the name and time only, *e.g.*

PITREAVIE 1200

The fundamental broadcast of British surface reports consisted of Section 1 of each collective. Section 2 of the collectives was broadcast at the end of the fundamental British broadcast or in the next available period.

Meanwhile, the number of reporting stations continued to increase, and the arrangements for collecting and distributing reports had again to be modified. From 10 May 1944 reporting stations were divided into two main sections as

[1] The Prebaratic was restricted to three issues until July 1945 when it was included in all four issues.

before—(*a*) full synoptic stations, denoted as 'S' stations and (*b*) other stations, denoted as 'O' stations, which usually sent only abbreviated reports; the 'O' stations were, however, divided into three approximately equal sets denoted as OA, OB and OC stations, and certain specially situated stations were denoted as OE stations. For convenience, the letters 'A,' 'B,' 'C' and 'E' were called the TELETRIP letters of the stations. Full reports from the 'S' stations were broadcast on the main teleprinter network as previously, but reports from the OA, OB and OC stations were broadcast on the main teleprinter network at certain hours only in rotation, OA at one hour, OB at the next and OC at the following hour. Reports from the 'O' stations which were not broadcast in the main teleprinter broadcast were broadcast on the second channel, simultaneously with the broadcast on the main network of the 'S' and 'O' stations. Thus, when stations OA were broadcast on the main network, stations OB and OC were broadcast on the second channel. All reports from the OE stations were broadcast on the main network. This schedule remained in operation until the end of the war in Europe.

Wireless Communications

Communications between the United Kingdom and overseas theatres, and within overseas theatres, were mainly by wireless. On the declaration of war in September 1939, all wireless transmissions of synoptic data in clear, from Great Britain, were suspended. These transmissions, full details of which are given in M.O.252 (12th Edition), consisted mainly of :—[1]

(*a*) National Collective Issues of synoptic reports from Air Ministry (GFA) including obsevations in code from British stations and ships. Reports from Iceland, the Faeroes and Azores were included in these messages and climatic data were added to two messages each month.

(*b*) Intercontinental Collective Messages containing collections of coded synoptic reports from stations in Europe, Siberia, North Africa and from ships, with climatic data added one day each month. These transmissions were made from Rugby (GBR), Learfield (GID and GIC) and Air Ministry (GFA) and were intended primarily for reception in distant regions.

(*c*) European Collective Messages containing coded synoptic reports from European countries and reports from ships in the eastern North Atlantic. These messages were transmitted from Air Ministry (GFA) and were intended for internal reception in Great Britain.

(*d*) 'Weather Shipping' Bulletins containing coded reports from ten British stations, Reykjavik and Thorshavn, and forecasts for the use of shipping in the seas around the British Isles. These messages were transmitted by Air Ministry (GFA), Rugby (GBR) and by certain G.P.O. W/T stations.

(*e*) Fleet Synoptic messages containing coded reports from a selection of stations bordering the eastern North Atlantic and from ships situated over the area 40° N. to 60° N. lat., and 8° E. to 45° W. long., together with an analysis. These messages were transmitted from Cleethorpes (GBY).

[1] A.M. File S.33731.

British and Allied meteorological units outside the United Kingdom had to be provided for during the war and special cyphers were introduced to meet their needs. Initially, transmissions were introduced on an *ad hoc* basis according to the users' requirements which differed considerably. The Fleet Synoptic W/T messages were restarted in cypher and cable messages containing synoptic information were instituted, at first for Malta and Gibraltar and later for Iceland and Russia. As for meteorological teleprinter communications, so for meteorological W/T communications, ETA was the main centre; a subsidiary centre was developed at Prestwick.

Plans were made in November 1939 to issue synoptic information in cypher by W/T to provide an alternative to the teleprinter broadcasts, in the event of a breakdown or dislocation affecting land-line communications. A code word (AOPORLI) was chosen for giving orders to put these plans into force and the issues were referred to as SYNDISI issues. The arrangements allowed for occasional trial broadcasts, the first of which was made on 10 May 1940.[1]

It was also arranged in July 1940 for meteorological reports in the British Isles to be collected by means of a stand-by W/T point-to-point organisation in the event of land-line failure; special cypher pads were distributed for the purpose in case of necessity. At the same time, arrangements were made for surface and upper air data from certain selected stations to be issued by W/T in cypher to Gibraltar and Malta in case of cable breakdown.[2]

Exchange of Information with Russia

It was arranged in August 1941 to send wireless messages containing a selection of synoptic reports, in cypher, four times daily to Russia. These messages were expanded in September 1941 to include a daily forecast in Previ code. In April 1942, upper air data were added to the messages once daily and in October the messages were again expanded by the inclusion of additional meteorological information, an analysis for the area of the European continent, British Isles and eastern North Atlantic to approximately 30° W. in respect of the 0100 and 1300 G.M.T. charts, and reports of locations of atmospherics. Also, in October 1942, the transmissions by W/T to Russia were increased to eight daily to include observations for all synoptic hours. The schedule was as follows :—

G.M.T.	*Contents*
0200	0100 G.M.T. Synoptic data.
0545	0400 G.M.T. Synoptic data.
0800	0700 G.M.T. Synoptic analysis 0100 G.M.T. U.A.T.s 136, 406, 501.
1130	1000 G.M.T. Synoptic data, Upper winds 146, 300.
1130	Forecast in Previ code.
1400	1300 G.M.T. Synoptic data.
1745	1600 G.M.T. Synoptic data upper winds 146, 300.
1900	1800 G.M.T. Synoptic data analysis 1300 G.M.T.
2345	2200 G.M.T. Synoptic data.

In addition to the issue of the 0545, 1130, 1745 and 2345 messages by W/T, cable transmissions also continued until January 1943, when all messages were sent by W/T only.

[1] A.M. File S.58106.

[2] A.M. Files S.58106 and S.77453.

(C45068) R*2

The transmitter used at that time for sending meteorological information to Russia was also used for special meteorological messages to Gibraltar, Malta, Middle East, Iceland and the Faeroes. Russia supplied synoptic and upper air data in cypher eight times daily by wireless and cable on a reciprocal basis. Point-to-point wireless trials were made with Moscow in April 1943, but lack of agreement prevented this method of communication being established at the time although, over a year later, in September 1944, duplex wireless exchange was introduced for four daily transmissions. Cable messages from Russia ceased in July 1943 as the wireless issues continued to be received regularly and reliably.

ALFIG and BULFEX Broadcasts

Meanwhile, periodic changes in cypher were made and by July 1942, when regular wireless broadcasts from ETA of synoptic data for Army exercises were made, SYNPAD was used. As there was some duplication in the various *ad hoc* transmissions it was decided in August 1942 to introduce a 'General Purpose Broadcast' termed ALFIG (**A**rmy, **L**isbon, **F**aeroes, **I**celand, **G**ibraltar). This was intended to meet the needs of the meteorological units with the Army and R.A.F. in the Field and of British and Allied Meteorological Offices overseas as well as to serve as a stand-by service for home units in the event of a breakdown of the teleprinter service.[1] The list of recipients in September 1943 included meteorological sections of, or units in, the following :—

1. *Tactical Air Force, United Kingdom*—
   - H.Q. T.A.F.
   - No. 83 Group.
   - No. 84 Group.
   - No. 483 Group Control Centre.
   - No. 484 Group Control Centre.
2. *Army Formations, United Kingdom*—
   - I, II, VIII and XII Corps.
   - I and II Canadian Corps.
   - Porton.
3. *U.S.A.A.F. in United Kingdom*—
   - H.Q. 8th Air Support Cmd.
4. *Overseas*—
   - Iceland.
   - Faeroes.
   - Gibraltar.
   - Malta.
   - Middle East.
   - British and American Forces in—
     - N. Africa (about 50 recipients).
     - Bathurst.
     - Rabat Sale.
     - Lisbon.
     - Stockholm.

By that time, the contents of the messages had so increased that continuous broadcast was necessary throughout the 24 hours except for four half-hour periods which were reserved for servicing purposes. But the growing demand for additional meteorological data from ETA necessitated the introduction of a second channel W/T transmission, and a new broadcast, termed BULFEX, began in May 1944.[2] The free periods on the transmitter were used for sending data to Russia.[3] The BULFEX schedule was extended later in 1944 to include hourly reports from stations in Southern England in order to meet the needs of the meteorological units with the liberating forces on the continent.

Expansion

The volume of meteorological W/T receptions and transmissions steadily increased throughout the war. It necessitated an increase in the signals personnel at ETA from about 30 to nearly 300, and towards the end of the war

[1] The first schedule compiled for these issues is given at Appendix 22.
[2] The schedule is given at Appendix 23.
[3] A.M. File S.77452

approximately 60 assistants were employed on cypher duties. The magnitude of the work on reception of W/T messages may be judged from the fact that, by December 1944, the average number of figure (coded) groups taken daily amounted to over 100,000.

With the entry of the United States into the war, wireless transmissions of United States reports ceased and arrangements were made for selected data to be exchanged in cypher using W/T point-to-point circuit between Prestwick and Dorval (Montreal). This link soon became most important and handled a large amount of traffic. The data were passed from Prestwick to ETA by the duplex teleprinter line. Meteorological W/T point-to-point circuits were also set up for the exchange of data between Prestwick, the Azores, Bermuda and Iceland.[1]

To facilitate the exchange between the meteorological offices at the Air Movement Control centres at Gloucester and Hendon and the Meteorological Offices in North Africa and on the continent, broadcast W/T channels were provided at these stations and also a number of meteorological point-to-point circuits.

Overseas

As in the United Kingdom, the meteorological communications organisation overseas underwent a striking transformation and expansion; additional reporting stations were set up, mobile meteorological units were formed, new forecasting centres were set up, all of which required facilities for sending and receiving information; ground-to-air channels were provided at all main staging posts for transmitting weather information to aircraft in flight. All collective broadcasts were increased both in regard to contents and frequency.

Particulars of the pre-war wireless weather messages issued by British meteorological offices overseas (Gibraltar, Malta, Middle East and Iraq) are given in M.O.252, 12th Edition. It is not proposed to give here the complicated story of the development of meteorological communications overseas but the signals plan can be consulted in A.M. File S.87404. The number of groups broadcast daily by Almaza (Egypt) rose from 3,000 in 1939 to over 20,000 in 1945.

In certain areas of strategic importance, where an independent meteorological service operated before the war, the communication facilities were considerably developed and amplified by the Meteorological Office. This expansion involved providing communications equipment and operating personnel from R.A.F. Reserves. The areas concerned were the West Indies, Bermuda, West and East Africa, India and Ceylon.[2]

* * * * *

The importance of providing exclusively meteorological channels for any large-scale collection and dissemination of meteorological information was shown in almost every operational theatre. Broadly, the course of events in most areas, where no pre-arranged plans had been made for meteorological communications, was as follows :—

(*a*) Meteorological units began to exchange data by means of 'addressed' messages in point-to-point operational or administrative channels.

[1] A.M. File S.69278.
[2] M.O.5 Folder 4/5.

(*b*) As meteorological traffic increased, so these channels became overloaded; delay cound not be avoided without the allocation of a very high priority which could not be granted.

(*c*) Attempts were made to make ' fixed time ' transmissions but these could not be maintained because of the claims of more important traffic.

(*d*) Finally, it was found necessary to allot W/T frequencies, transmitters and receivers exclusively for meteorological communication.

In the early part of the war, a considerable W/T meteorological organisation was being built up overseas with little co-ordination, resulting in some cases in unnecessary duplication and, in others, in potential users being unaware of all the data available. The Meteorological Office removed such anomalies by collecting details of all meteorological transmissions and then circulating the information to all concerned. Other war-time difficulties in regard to collecting and disseminating meteorological data were the occasional lack of understanding by the Signals and Meteorological Officers of the other's problems, the serious loss of time sometimes caused by using receivers which needed the use of interchangeable sets of coils for the changing of frequency, the time spent on arranging for cyphers and recoding tables and the frequent change of W/T operators.

It is considered that for a future emergency :—

(*a*) Signals precedence for point-to-point working should be clearly agreed beforehand and plans include exclusive meteorological broadcast and point-to-point channels. It should be possible to go over to war routine at a given signal, each unit having precise instructions what to do.

(*b*) Provision should be made for co-ordinating meteorological W/T communications either by appointing liaison officers or by consultation between Branches, or both.

(*c*) Signals and Meteorological Officers in training should be given an insight into the other's work ; problems affecting both should be discussed so that agreed arrangements can be made.

(*d*) W/T reception at fixed stations should, as far as possible, be by local staff who should be liable to embodiment in the local armed forces in war. Needs vary so much from one station to another that special consideration of each case is necessary. At some isolated reporting stations overseas, work was carried on by a specially trained grade, observer W/T operator. Service W/T operators might be given some knowledge of meteorological work in their training.

(*e*) Stand-by W/T arrangements should be exercised periodically.

(*f*) A special W/T set or sets should be provided for meteorological use, covering at least 10 kc/s to 20 mc/s. Frequency change should be by switching, not by changing coils.

(*g*) Cyphering arrangements should be completed at an early stage in planning ; cypher staff in training should be given some knowledge of the special needs for meteorological work, and vice versa.

CHAPTER 29

TECHNICAL DEVELOPMENTS

Instruments

The facilities available for instrumental development work in the Meteorological Office were very limited in 1939 but were improved gradually during the war. Most development work was centred in the Instruments Branch (M.O.4) but, as a wartime measure, the design of radio-sondes was undertaken at Kew Observatory. In the case of meteorological instruments for use in aircraft there was close collaboration between the Instruments Branch and the Meteorological Research Flight at Boscombe Down and with Dr. G. M. B. Dobson, F.R.S., at Oxford University. The resources of the instrument manufacturers and the scientific establishments of other Government Departments such as T.R.E., R.A.E., N.P.L. and R.R.D.E. were drawn upon appreciably. Liaison with Dominion and Allied Meteorological Services was maintained, notably by the distribution, at as early a stage as possible, of copies of specifications of newly developed instruments.

The evacuation of the Instruments Branch from its pre-war location at South Kensington to Wycliffe College, Stonehouse, Gloucestershire, caused a considerable amount of dislocation of the work of the Branch generally, and since the supply of existing equipment to meet Service requirements was the urgent need, it was many months before facilities for development work could be provided. Some rooms in the Science Block of the College were eventually fitted up for this purpose but the arrangements were never wholly satisfactory, owing mainly to the shortage of accommodation.

The development of meteorological instruments during the war can be considered under four main headings : instruments normally used for surface observations ; those used for observations in aircraft ; those in which radio and radar are applied for upper air soundings ; those used in connection with investigations of radio propagation.

Normal Instruments for Observations

Owing to the limited effort available, work on the ordinary surface instruments was generally limited to such modifications as would facilitate production under war-time conditions and to designing a few new instruments to meet special requirements arising from the various services. In many cases, the standards of accuracy and finish which had previously been insisted upon, had to be relaxed in order that output might meet the very heavy demands.

Thermometers : The shortage of skilled glass-blowers made it impossible in 1942 to obtain enough thermometers of the sheathed type which had been adopted as the British standard in about 1936. As an emergency measure, a solid stem type of thermometer was introduced towards the end of 1942. This is easier to make, but firms found it very difficult to meet the specification in all respects and many sub-standard thermometers (*e.g.*, with dimensions not strictly correct and maximum thermometers with too narrow constrictions) had to be accepted.

Barometers : One of the major difficulties with mercury barometers is to prevent the entry of air into the tubes during handling and transit. In 1943, some experimental barometers were designed, in collaboration with the N.P.L. and Messrs. Short and Mason, to incorporate devices in the cisterns to prevent the entry of air. A comprehensive series of tests was planned but was held up by the discovery that contamination of the mercury was a cause of the trouble. Work on this was proceeding when the war ended.

With a view to ensuring safer transit of mercury barometers, a new device, called a 'barcrate,' was designed during 1944. The barometer, in its box, was suspended by stout springs in an angle-iron framework. The 'barcrate' was much more compact than the earlier type of barometer carrier (the 'dhoolie') and could be packed flat for return when empty.

Cloud Height Meters : The pre-war standard cloud searchlight was intended for permanent installation at fixed stations and, weighing more than 1 cwt. and being mains operated, was quite unsuitable for mobile units. During 1943 and early 1944 a portable cloud searchlight was designed and put into production in collaboration with Messrs. Best and Lloyd and Joseph Lucas, Ltd. The apparatus consisted of a motor headlamp in a simple adjustable mount and was supplied complete with batteries, 1,000 feet of cable and remote control switch.[1] It could be set up for use in a few minutes. A portable alidade was also developed for use with this outfit.

Work was started in July 1943 on a cloud searchlight, working on modulated light, for use by day as well as by night. This instrument was still in the experimental stage at the end of the war, at about which time work was started, in collaboration with T.R.E., on an alternative method in which pulses of light are transmitted vertically upwards and the time taken to travel to the cloud and back to a detector is measured by a technique similar to that used in radar instruments.

A special investigation was made in 1943 to determine the relationship between the intensity of daylight illumination on a horizontal surface and the height and thickness of clouds. The records were made by means of a sodium photo-cell, with very stable characteristics, and a thread recorder. It was decided that this was not a practical means of measuring cloud height and thickness. The results are described in M.R.P.s 145 and 237.

Visibility Meters : The original model of the Gold Night Visibility Meter had been developed in 1939; during 1940 the design was modified to give a larger range by using two compensating wedges of different optical density. Large numbers of this design were made in the workshops of the Instruments Branch. In 1941, a Mark II model incorporating a number of refinements, including the use of laminated plastic for the frame, was developed in collaboration with C. F. Casella and Co.[2]

The development of a night visibility meter using a photo-cell was started late in 1943. A simple arrangement using a motor-car headlamp as source and a selenium-cell and portable galvanometer as detector was tried out, first on an experimental basis and then at an operational station. A number of improvements were found desirable and arrangements were in hand for small-scale production when the war ended. The experimental work is described in M.R.P. 226 and the results of the operational trials in M.R.P. 236.

[1] *See* Appendix 24, Fig. 1.

[2] *See* Appendix 24, Fig. 2.

Anemometers and Wind Finding Indicators : A simple wind speed and direction indicator for use at airfields was urgently needed in 1939. The requirement was for an anemometer and wind vane which could be set up at an open site and transmit readings over a reasonable distance to dial indicators in the meteorological office and the flying control room. A cup anemometer which turned an electrical generator was therefore developed in collaboration with Messrs. Short and Mason.[1] The instrument indicates wind speed from 4 to 100 m.p.h. on one, two or three dials which may be up to 500 yards from the transmitter, the dial indicators being rectified current meters, graduated in terms of wind speed. For wind direction, a wind vane was designed in 1941 to turn a contact mechanism which switched on appropriate lamps in an indicator. A new wind direction indicator was developed in 1943 in which the 'Desynn' system of remote transmission of angular movement is used so as to give continuous indication of wind direction by pointers moving over circular dials.[2]

In parallel with these developments, various improvements were made to the standard cup anemometers of the contact and counter types. These improvements included shorter spindles, detachable cup arms to increase portability, conical cups to reduce over-estimation in fluctuating winds, improved bearings with better weather protection, the substitution of mechanical by mercury switches and the replacement of rectangular housings by symmetrical ones. The special needs of units in the field were met by the development of portable wind measuring equipment consisting of a small wind vane with direction dial surmounted by a cup counter anenometer and mounted on a six-foot sectional mast, all of which packed into a small hand case. In 1943, a recorder, on the lines of an original design by J. R. Bibby (Q.J. Roy. Met. Soc. 70, 1944, 277) for use with cup contact anemometers was developed in collaboration with Gent and Co.

In order to facilitate the testing of anemometers and other instruments, two wind tunnels were designed and constructed in the Instruments Branch. One with a 2-ft. 6-in. square working section, for speeds up to 45 m.p.h., was completed in 1942. The other, built later, was an open jet return circuit tunnel giving speeds up to 80 m.p.h.

Pilot Balloon Equipment : The M.O. pattern pilot balloon theodolite, designed in collaboration with Messrs. E. R. Watts, was brought into general use in 1939, but in 1940 a modified design, Mark II, was introduced mainly to eliminate backlash of the bevel gearing, the drive from the elevation worm to the worm wheel being direct and bevels only being used to transmit the vertical motion of the telescope to the elevation circle. In 1943, a Mark III model incorporating a fixed focus telescope and a detachable battery box was developed and was followed in 1944 by Mark IV with a re-designed optical system giving greatly improved definition.[3] All this development work was done in collaboration with Messrs. E. R. Watts, the makers of the theodolites.

The deterioration of pilot balloons in hot climates was investigated from time to time during the war. Packing in nitrogen was tried without much success. Yellow dyed balloons were also tried but showed no marked improvement over the normal types. Latex balloons made by the dipping process or

[1] *See* Appendix 24, Fig. 3.

[2] *See* Appendix 24, Fig. 4.

[3] *See* Appendix 24, Fig. 5.

by the patent 'Kaysam' process, were found to be more suitable than cut sheet balloons for tropical use. In view of a possible shortage of rubber in and after 1942, experiments were made, in collaboration with B. D. E. Cardington, with paper balloons. These gave reasonably satisfactory results in trials but were rather troublesome to deal with. Fortunately, the need to introduce them on an operational scale did not arise.

The difficulty in maintaining supplies of hydrogen in cylinders to stations in the field led to the development, in collaboration with B.D.E., of portable hydrogen generators. A high-pressure type of generator was designed in October 1941 to use ferro-silicon and caustic soda and to generate enough gas to fill the largest size of pilot balloon. The acquisition of a large stock of calcium hydride a year later led to the development of a smaller generator for the same purpose.

Aircraft Meteorological Instruments

Aneroid Barometers: The aircraft aneroid barometer, Mark I, used in meteorological flights in 1939 was designed on orthodox lines and was limited to a ceiling of 400 mb. In order to make it suitable for use with a static head, a pressure-tight outer case was designed in 1940. This, however, made the instrument unduly bulky for use in small aircraft; moreover the ceiling of 400 mb. was too low for the new meteorological flights using high altitude aircraft. In 1941, therefore, a specification for an aircraft aneroid barometer, Mark II, with a ceiling of 150 mb., was produced. A prototype, using the principle of the Kollsman altimeter, was developed by Messrs. Kelvin, Bottomley and Baird, and production models of this design proved very satisfactory.[1] Subsequently, a modified type, Mark IIIB, was introduced for use in pressure cabin aircraft.

Aircraft Psychrometers: The only type available in 1939 was the strut psychrometer, Mark II, which, while suitable for low-speed biplanes, was quite unsuitable for high-speed monoplanes. Various attempts were made early in the war to modify this psychrometer but it was not until a Mark VI model, a small metal-framed instrument which could be mounted outside the aircraft cabin window, was developed in collaboration with Messrs. A. C. Cossor, that the problem was satisfactorily solved, at any rate for multi-engined aircraft.[2]

For single-engined aircraft, in which an instrument mounted near the cabin would be affected by the slip-stream from the engine, remote indicating instruments were urgently needed. The first of this type was a mercury-in-steel thermometer with a large dial specially developed in 1940 for the Meteorological Office by Messrs. Negretti and Zambra. When this thermometer was fitted to high-speed aircraft, the radiation shield had to be modified to withstand the strain involved. The freezing point of mercury limited the use of this thermometer to relatively low heights. The need to measure lower temperatures led to the introduction in 1941 of an electrical resistance thermometer, covering a range from −60° to + 20° C., made by the Cambridge Instrument Co. In operational use, this instrument was found to be susceptible to vibration and the scale was too compressed to allow accurate enough readings to be obtained. A later model had a double range and change-over switch. Both types required a constant battery voltage.

[1] *See* Appendix 24, Fig. 6.

[2] *See* Appendix 24, Fig. 7.

Early in 1943, a very much better electrical thermometer for aircraft was developed. It is described in M.R.P. 112 and J. Sci. Inst. 24, 1947, 47. The essential feature is a compact Wheatstone bridge indicator. The changes in resistance of the thermometer element are balanced by means of a slide wire round the edge of a disc which is rotated by a control knob, the latter carrying the temperature scale (− 110° to +100° F.). A robust type of null-reading galvanometer is incorporated in the indicator. The thermometer element, which had hitherto been of a spiral form without any radiation shield, was replaced in December 1943 by a suitably shielded flat plate (knife-shaped) element with a view to achieving a more constant speed correction and less aerodynamic drag. In April 1944, this element was adapted for wet bulb use and the balanced bridge outfit was modified by the incorporation of a switch, for use as an aircraft psychrometer.[1]

Aircraft Hygrometers: As it is impracticable to use psychrometers at very low temperatures, owing to the difficulty in replenishing a frozen wet bulb, attempts were made to develop other types of hygrometers. Goldbeater's skin, which had been successfully used in radio-sondes, was tried as a humidity-sensitive element. In one form of instrument, its variation in length was measured by a change of inductance, while in another form the change in length was made to vary the width of a slit intercepting a light beam falling on a photo-cell. In both cases, the fragile nature of the gold-beater's skin made the instruments unsatisfactory when fitted to aircraft. A more promising method was devised by Dr. E. Gluckauf, working at Durham University, who made use of the optical properties of thin hygroscopic films. The main difficulty in this case was to produce films of sufficient stability, and the war ended before a satisfactory aircraft instrument was produced.

The only hygrometer which was successfully developed for aircraft use, particularly in low temperatures, was the frost point hygrometer designed by Dr. G. M. B. Dobson of Oxford and Mr. A. W. Brewer of the Meteorological Research Flight.[2] It is described in Proc. Roy. Soc. A. 185, 1946, 144. In this instrument, a jet of air from outside the aircraft is projected across the top of a thimble at one focus of an elliptical reflector, at the other focus of which is an electric lamp. The thimble is cooled from below by a jet of a petrol-plus-carbon dioxide mixture or by liquid oxygen and its temperature is measured by a resistance thermometer, the platinum wire of which is wound round the thimble. The appearance of dew or frost on the thimble is observed through a magnifying lens. In a later development a photo-cell replaced the eye as detector of the dew or frost.

Applications of Radio to Meteorology

Radio-sonde: On the outbreak of war, the British radio-sonde was still in the early development stages at the N.P.L. The first radio-sonde stations in this country were accordingly equipped with French and Finnish instruments, while the design of our own apparatus was being pushed ahead at Kew Observatory. The general principles of the N.P.L. instrument were retained, but big improvements were made, especially as regards reducing the weight and simplifying the humidity element.

[1] *See* Appendix 24, Fig. 8.

[2] *See* Appendix 24, Fig. 9.

The first production instruments, the N.P.L., Mark III radio-sondes, became available in the late summer of 1940, in time to prevent a serious gap after the end of supplies from the Continent. The Mark III had no humidity element and the pressure and temperature signals both functioned continuously. The Kew Mark I radio-sonde, which was developed in the summer of 1941, was fitted with a windmill-operated switch which connected the pressure, temperature and humidity elements in turn to the main radio circuit. The chief subsequent modifications were a change in the circuit in 1944 (Kew Mark IA) and improvements in the radiation shielding of the temperature unit.[1] Full details of the instrument are given in M.O.462. Reports on the performance of the instrument were given in M.R.Ps. 202 and 206, and errors of upper air temperature and pressure measurements from radio-sonde and aircraft observations were reviewed in M.R.P. 205. Early in 1945, work started on simplifying the construction of the Mark IA radio-sonde for mass production.

Radio Wind Measurement: The ordinary pilot balloon technique for measuring upper winds suffers from the severe limitation that the winds can be determined only to the height at which the balloon is lost from view, *e.g.*, the winds above a cloud layer cannot be determined. Shortly before the war, the N.P.L. co-operated in developing a technique for following a balloon-borne radio transmitter by radio D/F methods. The equipment and technique are described in M.O.464.[2] By simultaneous measurements of the azimuth of the transmitter from two or, preferably, three, stations 20 miles or so apart, and a knowledge of the height of the transmitter, it is possible to determine the speed and direction of the upper winds. The height can be computed from the signals of a radio-sonde transmitter. As an economy measure, where it is only desired to measure the wind and not the other meteorological elements, a special radio-sonde was developed, the W/F Mark VI, which only had a pressure element. In this case, the temperature distribution has to be assumed before the height can be calculated.

It was recognised from an early date that radar techniques offered an alternative to the N.P.L. method, but not until 1943 was a suitable radar set, the G.L.III, available for trials. The results showed that the radar method was in general the more accurate of the two, and it also had the great advantage of being operated from a single station. The most serious limitation of the G.L.III was that its range was limited to 36,000 yards, but a ' range doubler ' was developed in collaboration with R.R.D.E. to extend this to 66,000 yards.

In order to make use of the radar set, a reflector had to be attached to the balloon and the only available type was a metallised paper corner reflector designed by R.R.D.E. Efforts were made to design a lighter, larger, more compact (when dismantled) target with lower aerodynamical drag, but nothing new was in production at the end of the war. Wind finding technique by the radar method is described in M.O.M.468.

Tests were made in operational Commands of other radar sets, notably the G.L.II, for wind finding, but none of these was ever made available for exclusive use by the Meteorological Office. A comparison of heights measured by the radio-sonde and radar methods was reported on in M.O.M.203.

Radio-sonde Theodolite: In 1943, the forecasting branches laid down a specification of requirements for a new precision radio-sonde, capable of giving information about all the usual meteorological elements, including wind, much more accurately than existing methods. It was decided that this problem could best be tackled by designing a chronometric radio-sonde transmitting on the centimeter band which could be followed by a micro-wave theodolite. Development began in 1944 on the chronometric unit at Messrs. Kelvin, Bottomley and Baird, and on the micro-wave transmitter and receiver at the British Thomson-Houston Co. In June 1944, the responsibility for co-ordinating this work was handed over to the Director of Communications Development (D.C.D.), Ministry of Supply, and the D.M.O./D.C.D. Advisory Panel was formed. The project was still in the early development stages at the end of the war, but a prototype chronometric unit was almost completed.

[1] *See* Appendix 24, Fig. 10.

[2] *See* Appendix 24, Fig. 11.

Batteries: The original N.P.L. radio-sonde was intended to be used with a dry battery but it was soon realised that a more efficient, lighter battery could be produced on the lines of the Finnish radio-sonde battery which has zinc-lead oxide and sulphuric acid cells. Such a battery was developed with help from the Barnard Battery Co. and was brought into production in 1940. The power requirements for the micro-wave radio-sonde were greater than for the standard radio-sondes and a more efficient type of cell was designed in 1944/45 so as to keep the overall weight within reasonable limits.

Sounding Balloons: Large balloons for radio-sonde work were obtained chiefly from France at the beginning of the war, but the Guide Bridge Rubber Co. developed a satisfactory latex balloon made by the Kaysam process. Comparisons with American neoprene balloons in the later stages of the war showed that the natural latex balloon was markedly superior.

Parachute Radio-sondes: Some experimental work was done early in 1945 to produce two types of parachute radio-sondes, the first to be dropped by aircraft over enemy territory and the second to be released from a long range constant height balloon. Neither project had reached a successful conclusion at the end of the war.

Meteorological Equipment for Radio-Propagation Investigations

The effect on radio-propagation of atmospheric conditions near the ground, especially in causing the transmission of signals over abnormal distances, was the subject of a number of investigations which were co-ordinated by the Joint Meteorological Sub-Committee of the Meteorological Research Committee. These investigations necessitated using special instruments and techniques for observing and recording the vertical gradients of temperature and water vapour content in the first few thousand feet above the ground. The radio-sonde could not be readily adapted for the open scale which this work demanded. Aircraft observations made by special meteorological flights were used to some extent but a large part of the work was done with instruments on captive balloons and on a tall tower.

Rye Temperature and Humidity Gradient Equipment: One of the 350 feet radio towers at Rye was chosen at the end of 1942 for mounting temperature and humidity elements at heights of 4, 50, 150, and 350 feet in order to obtain continuous records over long periods. The thermometer elements were of the electrical resistance type. For humidity, the Gregory humidiometer, production of which had just been started by Messrs. Negretti and Zambra, was used. In this instrument, the elements consists of a fabric, on a cylindrical former,

impregnated with hygroscopic salt, the electrical resistance of which varies with humidity. Both temperature and humidity elements were connected to thread recorders at ground level. For the first year's operation, the elements were housed in small Stevenson screens without artificial ventilation. In 1944, special screens having electrical aspiration were constructed and led to greatly improved results. A report on the apparatus is given in M.R.P. 240.

Balloon Psychrometers : For the early experiments with captive balloons, an ordinary pattern baro-thermo-hydrograph, normally used for surface observations, was modified for use on a balloon, but its excessive lag and the lack of artificial ventilation soon led to the development of an aspirated psychrometer for balloon use. The first model was adapted from a thermo-couple instrument designed at I.C.I. for use in fog investigations. Aspiration was provided by a small electric fan and records were obtained by photographing deflections of the galvanometer connected to the thermo-couples, the cold junction of which was immersed in liquid in a thermos flask. Towards the end of the war, a more robust and portable apparatus was needed for experiments to be made from boats, and an electrical resistance psychrometer was designed, the balanced bridge indicator used on aircraft being adapted as the measuring instrument.[1]

Testing, Maintenance and Calibration of Instruments

In addition to the development work in the Technical Section of the Instruments Branch and at Kew Observatory, the routine testing, maintenance and, where needed, calibration, of instruments were undertaken. The enormous increase in this work, which demanded the introduction of more up-to-date and larger test equipment such as pressure, temperature and humidity chambers, may be judged by the following numbers of instruments tested each year :—

Year	*No. of Tests*	*Year*	*No of Tests*
1929–33	4,700 (average)	1942	41,600
1939	11,700	1943	47,400
1940	22,900	1944	61,400
1941	24,200	1945	51,200

During the war, 1,748 balloon theodolites and 25,196 aneroid barometers (many of which were required for the Navy) were individually tested.

All radio-sondes and most of the aircraft meteorological instruments were individually calibrated. A total of about 20,000 radio-sondes were calibrated at Kew Observatory and Larkhill during the war. All radio-sondes recovered after ascents (these amounted to nearly 40 per cent of those released) were examined at Larkhill and those which were not too badly damaged (roughly 75 per cent of those recovered) were reconditioned and recalibrated for further ascents.

In addition to preparing specifications and engineering drawings of newly developed instruments, full instructions for their installation, operation and maintenance were prepared and issued. On an average, 13 new specifications, 138 individual drawings and 11 instrument instructions were produced yearly during the war. Corresponding averages for the peace-time years 1920–39 were 9, 32 and 6 respectively.

[1] *See* Appendix 24, Fig. 12.

Analyses and Forecasts[1]

Analyses

The modern ' frontal technique ' originated in the work carried on in Norway towards the end of 1914–18 war, the fundamental idea being that of discontinuity in the field of air density, depending mainly on the temperature. The actual term ' front ' was introduced a few years later, replacing ' steering-line ' and ' squall-line '. It denotes a line of separation between cold and warm air masses but it is normally a line of discontinuity in the field of pressure gradient, involving cyclonic shear of geostrophic winds.

Little upper air data were available at first, but it was always realised that the physical basis of the empirical technique must be three-dimensional. On the investigational side, the application of upper air data began immediately after the first world war, based mainly on observations made during the war, and a considerable measure of verification of the Norwegian ideas was obtained. It was always realised that the sharpness of the discontinuity decreases upwards but that the magnitude of the temperature variation over a 12-hour time interval, or over a horizontal distance of a few hundred miles, is often greater in the middle and upper troposphere than it is near sea level, especially in a westerly situation in the area around the United Kingdom. It was verified that there is frequently a real undercutting of the warmer air by the cold, though the sloping boundary is often smoothed from an ' inversion,' *i.e.*, an increase of temperature with height, to an almost isothermal layer or to a layer with a small lapse of temperature.

The Norwegian discovery, as early as 1920, of the life history of depressions in relation to fronts may be regarded as an even greater achievement than the identification of fronts as a normal atmospheric feature in temperate latitudes, especially in view of the rarity of newly formed depressions in Western Europe. What proved to be a broadly correct descriptive picture of the development in three dimensions was available not long afterwards.

Though intensive study of scattered upper air observations in relation to past cases led to a considerable advance in understanding atmospheric processes, the amount of upper air information available between the two wars was inadequate for purposes of current analysis and forecasting. A well-marked front is associated, in particular, with a discontinuity in the pressure gradient and can be clearly traced whenever there is a good network of surface observations, but an adequate system of analysis cannot be limited to such cases. It was not till 1933 that fronts were published in the Daily Weather Report (International Section) of the Meteorological Office and the quality of the published analyses in a number of countries fully justified this delay. Judging from these published analyses, the standard in this country in the years immediately preceding the outbreak of war was much the same as in Norway, the ' home ' of frontal analysis, and higher than in many other countries. Four charts daily were included in the International Section, two of them covering a substantial area. It was the only publication in any country where fronts could be regularly followed on a six-hourly basis, which is generally essential for proper continuity.

[1] Explanations of the technical terms used in this section may be found in ' The Meteorological Glossary ', M.O.225 (ii) (A.P. 897).

Over the Atlantic the analysis had to be based entirely on surface observations, and until the Meteorological Flight was formed at Aldergrove in 1947, this was also the case over most of the British Isles. In many situations, chiefly in winter, when air currents were on a large scale and fronts were fairly definite, good analysis was possible, but there were also many situations when surface data were inadequate. Sometimes the fronts were left out, and sometimes there was an attempted analysis made with little confidence.

In the earlier part of the war good analysis was possible in the British Isles, but not as a rule on the Atlantic where, for long periods, there were not even surface observations. The approach of a warm front could sometimes be deduced from upper air observations in this country, particularly strong upper north-westerly currents, but this obviously meant that the strong upper current was not itself predictable. Frontal analysis was made much easier by information supplied by meteorological reconnaissance flights and by the meteorological reporting ships; and before the end of the war the position was better than ever before. Cold fronts and occlusions could often be followed from America to the British Isles with no serious breaks in the continuity. The main features of the distribution of pressure and temperature were known over the whole area right up to the stratosphere; there was also some knowledge of humidity, especially in the lower troposphere where it is most important.

The terms 'cold occlusion' and 'warm occlusion' were introduced in 1941 to denote those occlusions which assume the characteristics of cold or warm fronts respectively, and specific methods of marking them on both working charts and published charts were adopted. Special symbols were also introduced for frontogenesis, frontolysis and instability fronts. The nature of instability fronts is referred to in the next section.

Frontal Analysis : The great increase of data and consequent increase of knowledge of atmospheric structure gained during the war did not make it possible to produce a uniquely determined frontal analysis over the whole of a large area. The boundary between air masses is sometimes a zone of transition rather than a discontinuity, but must still be entered on a chart if the analysis is to give a comprehensive picture of the atmospheric structure. It is possible to fix a more or less arbitrary convention as to where to place the front, but none can be really satisfactory, especially from the three dimensional standpoint.

It became increasingly recognised that the well-defined discontinuity at sea level and the frequent existence of cold air below warm air are due to convergence, which has a maximum low down and is normally replaced by divergence at medium levels. Convergence involves a departure from geostrophic motion, which is due mainly to the acceleration, and it is especially pronounced ahead of a newly formed depression.

The field of convergence and divergence affects not only the front iteslf but the adjacent air masses. Its effects are cumulative and the formation of a deep damp layer, which is very important for rainfall, may take days. It is usually a process of piling up the moist air from below. Some fronts with a large temperature difference, generally spread over some hundreds of miles, produce little rain, while very minor fronts can produce much rain in deep damp air, especially if there is even a slight degree of instability.

Associated with these dynamical processes is an important class of quasi-frontal phenomena. There is a tendency for rain to develop along belts in a manner not yet really understood; they are vaguely related to the vertical wind shear (thermal wind) but the relationship is not simple and it is not known what range of height should be considered. When cumulo-nimbus clouds form in a long belt, severe line-squalls may develop as the result of cooling by precipitation even when the initial temperature difference is very small. The squall provides a self-perpetuating mechanism to the whole system so long as the conditions of instability persist. The term 'instability front' was introduced for these cases. There are also rain-belts without definite instability, which may resemble occlusions. At one time the term 'pseudo-occlusion' was used to describe such phenomena but it was omitted from the Combined Analysis Code (referred to in next section). In practice it was difficult to limit 'occlusion' to fronts with an orthodox history but, on the other hand, it was undesirable to use the term for any rain-belt not related to a warm or cold front, and the term 'line of convergence' was more useful particularly in view of its importance in the tropics. Some rain-systems were merely described in forecast bulletins and not included in the Baratic or Prebaratic messages[1]—an obvious necessity in the case of rain areas not in definite belts.

The tendency for ascent and convergence to develop along a line has considerable importance for frontogenesis and is one reason for the very existence of fronts. Though some situations, *e.g.*, at the trailing edge of the cold air brought southward by a moving depression, favour more or less straight fronts, the difficulty is usually not why fronts should have curves and bends in them, but why they should ever be straight. The bends, which are so important for future development, are a natural consequence of the irregular motion of the atmosphere.

The degree of complexity of the atmospheric structure depends partly on the size of the isobaric systems and associated air currents, and is on the whole greater in summer than in winter. The warmth of the continent in summer is an additional reason for this. Thus, for short period aviation forecasting the analysis had to be more detailed than for general forecasting, and required an intensive study of a limited area or a particular route. For detailed cloud forecasting, humidity is of prime importance and its distribution may differ considerably from that of temperature. This complication and the frequency of marginal cases introduced a subjective element into frontal analysis. Fronts which are not major air mass boundaries may be very important for local weather, but their life history is often brief. There are differences of opinion on this issue, but the observed variation of wind with height appears to be unfavourable to the continuity of complex structures. This is specially obvious in warm summer and autumn situations when the movement of rain areas and isobaric systems is often determined by the winds at medium levels, where the vertical velocity probably has its maximum.

The policy at the Central Forecasting Office was to obtain the maximum possible agreement for the fronts given in the Baratic, and not to attempt to explain all continuous precipitation in terms of fronts. It was inevitable that in some parts of the charts there would sometimes be phenomena of a frontal type which were not included in the Baratic, owing to the limitations of time.

[1] *See* Chapter 3.

Moreover frontal phenomena are often bound up with local factors, so that effective detailed analysis requires a first-hand knowledge of the area. An experienced ' local forecaster ' should always be able to make a better analysis and forecast in his area than a forecaster at some distant centre.

The development of high altitude flying during the war, and especially the ' Pampa ' flights, led to a vast number of observations of medium and high clouds, which had not been fully studied by the end of the war. Much attention was given to ' lanes ' in frontal cloud systems, which in most cases, were found where there was not much precipitation. In fact, routine aeroplane soundings for the last twenty years had proved that during moderate warm front rain the clouds are generally continuous from a low level to at least 600 mb.—and generally to above the 400 mb. level ; there may sometimes be gaps between the medium and high cloud but the thickness of the rain-clouds is rarely less than 15,000 feet. The medium clouds ahead of the rain may be either layered or continuous, but if they consist of ice crystals they tend to diffuse over a great vertical extent. The classical Norwegian model of the warm front was based on cloud observations ahead of rain-producing warm fronts north of latitude 60°, where ice-crystal clouds predominate at medium levels for much of the year. The earliest models made the cloud system too thin in the rain area, but this was soon rectified, and the improved model remains a good one for typical rainy warm fronts. Subsidence effects in the cold air were introduced into the later models. War-time experience emphasised the need for supplementary models, especially as frontal analyses revealed many fronts without much rain ; it also showed that new models are needed for cold fronts and occlusions. This work could not be done satisfactorily until all the relevant data had been carefully examined ; the pressure of routine work rendered this impossible during the war.

The proper method of representing the so called ' surface of discontinuity ' was also found to present difficulties. Vertical soundings may show a transition from cold air to warm air ahead of warm fronts, and behind some cold fronts, but the boundary is generally smoothed and the degree of smoothing increases up the slope. Hence, it is necessary to introduce some kind of transitional region into the models, instead of a boundary surface. Well-marked cloud boundaries at high levels were frequently found to be humidity boundaries in a region of continuous temperature gradient.

The amount of attention which it was possible to devote to the detailed structure of the atmosphere, of which the lower layers ar most important for frontal analysis, was limited by other urgent demands. Nevertheless enough was done to make it reasonably certain that no simple generalisations were possible, and that no chance of readily obtainable progress in forecasting technique was missed. The mass of new upper air information revealed an atmospheric structure of great complexity and it was realised that only research on a large scale could be effective, a scale impossible of achievement during the war within the limited resources of the Central Forecasting Office.

It was found that the introduction of quantitative observations in three dimensions over a large area made detailed air mass classification largely superfluous. Terms such as tropical air and maritime polar air are very useful for descriptive purposes, though really precise definitions are difficult and perhaps undesirable. To obtain maximum precision would require a classification too large and cumbersome to be of any practical value. Full weight would

have to be given to dynamical factors, or else the classification would lag far behind the actual technique now in daily use, limited though this is ; the absence of clearly defined boundaries in the upper air would also present a grave difficulty.

Upper Air Analysis : It was early discovered that a front can sometimes be identified at 700 mb. and more rarely at 500 mb., but that in many cases the genuinely frontal features are limited to the layer below 700 mb. while higher up there is only a transitional zone. This, together with the increasing realisation of the subjective element led to a sharp decrease in the number of fronts marked on upper air charts—the use of which was particularly a war-time development. War-time demands compelled the Upper Air Branch to concentrate on the correct drawing and forecasting of the 700, 500 and 300 mb., surfaces, and what was called upper air analysis actually meant the correct drawing of the contour charts for these surfaces and the ' thickness lines ' (isopleths of the thickness of the layers between the surfaces), which had of course to be mutually consistent. The network of stations was much wider than at sea level, more especially over sea areas, and during most of the war there were large gaps in the observations, and knowledge and skill were required for a correct drawing. Moreover the standard of accuracy of the observations in the upper air was less than at sea level. Observed winds could be used for drawing contours, subject to allowance being made, as necessary, for the departure from geostrophic balance associated with the acceleration.

In interpolating the thickness lines (which depend on the mean temperature of the layer of air to which the thickness refers) in areas where upper air temperature is not observed, the meteorologist must take into account all previous relevant observations, the surface fronts and their movements, and the general wind structure, in particular the network formed by the thickness lines and absolute contours, including the surface isobars. The geostrophic wind gives a fair approximation to the horizontal movement of the air mass, but allowance also has to be made when necessary for warming by subsidence and by heat diffused upwards from the surface by convection. Surface cooling is much less important as it is confined to a shallow layer when one is dealing with short time intervals, but the cooling by radiation (especially from cold particles) of a warm air mass is not always negligible. It was learned that it is often the pattern of thickness lines rather than the actual thickness which are advected.

In a large area with only surface information, the lapse-rate could be estimated from the history of the air mass, the distance of the fronts, the pressure distribution (more especially the cyclonic or anticyclonic curvature) and the observed weather ; it was found that if these features were sufficiently definite the estimate should be fairly good.

Thickness Lines and Fronts : If the temperature field is continuous, the thickness lines give a better representation of the reality than does a front. Hence there developed a tendency for thickness lines to replace fronts for certain purposes, especially in relation to general large-scale development. The fronts remained important, especially in relation to the rainfall and clouds but the detailed relationship between thickness lines and fronts had still to be worked out ; this may prove to be very important. The following paragraphs summarise the experience gained both before and during the war.

The majority of depressions form on quasi-stationary fronts, and in such conditions the front is closely parallel to the thickness lines all through the troposphere. Subsequent developments move the fronts through great distances,

and a departure from parallelism of the thickness lines and fronts easily arises, and once it has started the component of thermal wind across the front may give rise to increasing departures from the simple initial state.

Subsidence warms both the cold and warm air masses in the high pressure areas and reduces the depth of cold air, so that there is a thermal wind between the low and high pressure area which often has a component across a front, whether it is oriented north-south or east-west, generally giving a forward shear aloft across the sea level front. At a warm front, this carries the rain far forward and lowers the angle of slope, while cold fronts often lack a genuine sloping boundary surface. Frontal structures are normally complex and vary considerably both along the front and in a 24-hour time interval. When a warm front travels thousands of miles on the Atlantic it is doubtful how far strict continuity is attainable. Frequently there appears to be frontogenesis ahead of the original front, associated with the forward shear of the warm air aloft, together with the warming of the residual shallow cold air by the sea surface, and probably by mechanical mixing also. It has been suggested that this forward shear may be a necessary condition for the movement of a front over any large distance. It is not a case of simple advection, but of the dynamical relation of shear to convergence and divergence at different levels, and therefore with the transfer of the pressure field which must accompany the movement of a front.

Fronts which are quasi-stationary for periods of days are largely limited to the perimeters of warm anticyclones, which have a wind circulation extending through the whole troposphere. The cold air comes round depressions and a long trailing front may be left behind by a moving depression. In such conditions the fronts tend to become parallel to the thickness lines, but small deviations from parallelism may be important in connection with the formation of new ' waves " and their deepening.

If wedges or cold anticyclones develop markedly in middle latitudes the front is carried far southward before it can become stationary. The front often goes round the southern boundary of a new anticyclone but owing to subsidence the region of maximum thickness gradient is soon transferred to the north side, where a new front may form if other circumstances are favourable.

At the end of the war, it seemed probable that the idea of a surface discontinuity extending through the troposphere might be replaced in most situations by that of a zone of steep thickness gradient, *i.e.*, of strong thermal wind, but that fronts would continue to have great importance, mainly as a low-level phenomenon.

Forecasting Technique

Prebaratics : Forecasting was based essentially on a qualitative assessment of the situation as a whole. So much information was required to assess accurately the weather conditions within a period of 48 hours that, even if available, no one forecaster could hope to master it in the time at his disposal. The 24-hour forecast had to be based on the latest chart, and any sacrifice of this principle in order to study back charts in greater detail could only lower the standard of the forecasts, unless this were done as supplementary work with the necessary allocation of staff.

An important part of the art of forecasting is to select for special study those areas which are most relevant to the particular problem in hand. If the best results are to be obtained for the British Isles in a difficult situation, little time can be devoted to areas which are not relevant, *e.g.*, to eastward in a pronounced westerly type.

The methods, developed during the war, of constructing the Prebaratic charts were briefly described in S.D.T.M. No. 44 and the standard of accuracy in forecasting frontal positions was written up in S.D.T.M. No. 90. Though the prebaratic charts put some of the forecaster's conclusions into a quantitative form, the actual processes by which the conclusions are reached are mostly qualitative only. At the end of the war there seemed to be no early prospect of exact computations of future pressure. Changes of sea level pressure measure the integral of the divergence of momentum in the overlying column of air, and depend on departures from geostrophic motion, which are small compared with the wind itself and are of the same order of magnitude as the errors of observation. Large departures from geostrophic motion can sometimes be recognised (and these were taken into account in drawing the upper air maps) but their excess over the observational errors, and over the casual variation of wind over short periods (*e.g.*, 10 minutes) are not large enough for the application of quantitative methods. Moreover the observed change of pressure need only involve a very small divergence through a thick layer, and is usually the difference between divergences of opposite sign in the upper and lower troposphere, *i.e.*, it is a small quantity of the second order. There remained the possibility of a qualitative forecast of the upper divergence deduced from the predicted accelerations, which could help in forecasting the development and decay of sea-level isobaric systems in addition to their movement. At the end of the war, some progress along these lines could reasonably be hoped for, but it was not certain how much it would amount to.

Thermal Steering : The field of barometric tendency continued to be the most powerful single weapon at the disposal of the forecaster ; simple extrapolation was found to work well for short time intervals. For periods of 24 to 36 hours ahead there were found to be cases when ' thermal steering ' (*see* S.D.T.M. 44) gave considerably better results than could be obtained from tendencies, especially with curved thickness lines as, for example, round a ' cold pool ' or a warm air mass, which do not always coincide with sea level depressions or anticyclones respectively, or with thickness lines which fan out or converge together. This kind of application of upper charts to forecasting was first used in Germany, which had a network of upper air stations before the war, but the method, originally called ' stratospheric steering,' was empirical and lacked a dynamical basis. The method made use of the measurements of the heights of the tropopause on international days, and was based on the fact that the more persistent isobaric systems extend right up to the stratosphere. There is a high correlation between the upper air pressure and temperature, and the height of the tropopause, and as the method was only a very rough one it could be made to work if any of these variables were used. As regards the dynamical aspect, the most widely held opinion in the United Kingdom was based on a paper published by Sutcliffe in 1939 Q.J. R.Met. Soc. 65 p. 518) on the effect of the thermal wind in the troposphere in the field of divergence. During the war, charts showing the thickness lines for the layer from the 1,000 to 500 mb. surface superposed on the surface isobars were found

to be specially useful for judging the steering effect, and also for studying general problems of development. The use of such simplified charts had some advantages over the use of a number of charts with more information in them, which no one man could digest in the short time available. It was soon realised that the half of the atmosphere below the 500 mb. surface is of the greatest importance and it was thought that until a better knowledge of this region had been obtained there would be little hope of obtaining anything additional from charts at higher levels; the more detailed study of the region below 500 mb. was, of course, necessary for other purposes. The principles of thermal steering are only simple when applied to the smaller and newer isobaric systems; the problems raised by larger systems are more difficult.

The Problem of Development: What proved to be à substantially accurate description of the life history of a depression in three dimensions was available many years before the war. The fundamental features were the wedge of high pressure over the warm sector, the upper trough which develops behind the cold front, and the forward displacement of the wedge and trough during the evolution of the depressions. It was known that in the final stage, the depression often has a vertical axis right through the troposphere and tends to become stationary, but that often after a stationary phase a slow movement is common, especially when the depression is rapidly filling. Experience had shown that in such cases the movement is in the direction of the strongest winds, although the lack of symmetry might not extend to the central region. The distinction between cold and warm anticyclones, and the evolution of one into the other, had also long been recognised, and was in fact pointed out by Hanslik early in the present century.

Indeed, progress towards a better understanding of the dynamics of these problems began later than the descriptions of the facts. Such progress may be said to have started with a paper by J. Bjerkness in 1930 (Oslo Geof. Pub. IX, 9) relating the curvature of upper troughs and wedges with the field of divergence. A number of further contributions to dynamical theory were made both before and during the war, and led to a gradual improvement in our understanding of the atmosphere. The innovations of upper air charts provided a means of applying this knowledge in daily forecasting, but in practice, it brought about no major advance. The precise influence on forecasting of this better understanding of the atmosphere was one of those imponderables which could not be measured, but it was certainly appreciable, and it could be expected to increase.

Before the war, a considerable amount of mathematical theory had been devoted to the discussion of waves on a surface of discontinuity, but this could never be brought into proper relation with the facts. War-time experience confirmed the pre-war view that it was necessary to revise ideas about surfaces of discontinuity and it remained to be seen whether the new ideas would prove compatible with the classical theory of frontal depressions.

Prontour Charts: The practice at the Central Forecasting Office was to construct upper air forecast charts, giving predicted contours, or ' Prontours ', from the surface upwards. In theory, there may be little to choose between the levels to be used for the building up process, but in practice the surface chart must be the main one, owing to the much closer network of stations. Moreover, newly formed depressions and anticyclones show up much better at sea level than they do aloft. Any warm sector depression only exists *as a depression* at a low level. Another point is that the bulk of the moisture is in the lower layers. It is only in some complex summer situations that the 700 mb. chart may provide a better basis for forecasting movement and development than the sea level chart. The most probable reason for this is the raising of the level maximum vertical movement.

The construction of forecast upper air charts was based on predicted thickness lines for each successive layer. The main principles have been briefly indicated above in discussing upper air analysis in areas without observations, and they would still be applied even if the network of observations were so good that the drawing of the current chart became largely a matter of routine. There is no doubt that any advance towards a more quantitative treatment of such problems as subsidence and convection, and the transfer of heat and moisture from sea or land to air would help in the construction of forecast upper air charts, besides having other forecasting applications.

It was realised that forecast upper air charts must show a logical sequence of changes and look reasonable in themselves. If they do not, the reason might be that the surface prebaratic from which they are built up is erroneous and requires amendment. The full possibilities of this cannot be known until the Prontours refer to a 24-hour time interval (which was not introduced during the war), but it would appear that such cases are not numerous. Only experience over a long period can show its possibilities and realise them in practice.

War-time experience showed that ' the cold pool ' is undoubtedly one of the most important features of upper charts, especially near the British Isles. Upper air charts showed that, though most of them are dying depressions, there are some persistent ones which do not coincide with a sea level depression, especially in summer; not only do they appear to exert a steering influence all round them, but they affect vertical stability, and when moving they affect the field of divergence low down; it was found that though their average movement in the area covered by the charts drawn at the Central Forecasting Office is towards south-east they are liable to move from any direction, and their behaviour was by no means understood. A really cold air mass over a warm sea is heated from below very rapidly, and the whole column of air is warmed by convection, but at a later stage this process becomes slow and it appears to be balanced for days together by a loss of heat above, presumably by radiation from cloud particles. Thus it may be that radiation aloft is not always a negligible factor, especially for forecasting beyond 24 hours.

Special Problems

Thunderstorms: The use of tephigrams for forecasting showers and thunderstorms was well developed before the war, including the application of Sir Charles Normand's work on the wet-bulb potential temperature, and the increase in basic data during the war led to more accurate forecasting for short periods. Great importance is attached to the depth of penetration of convection and its extension above the freezing level. The main criterion for instability is that for ' latent instability ' as defined by Normand. The saturated adiabatic lines on the tephigram are marked according to the wet-bulb potential temperature. Broadly speaking, the criterion for deep convection is that the plotted wet-bulb readings at low levels should be on a higher (interpolated)

saturated adiabatic line than the dry-bulb readings in the middle troposphere, though the difference need not be large. The newer ideas of convection, which were introduced by J. Bjerkness several years before the war and which were written up during the war in S.D.T.M. 102 'Convection in Theory and Practice,' were difficult to apply in practice, since the ratio of the area of ascending to that of descending air can be very small. Thunderstorms often develop along lines of convergence of a quasi-frontal character with large clear spaces between them. Nevertheless the points made in S.D.T.M. 102 proved useful inasmuch as they gave a bearing on the number of showers or thunderstorms which can develop in a given area, and on the possibility of any development in some marginal cases. For forecasting 24 hours ahead the stability has to be estimated, and owing to the number of factors involved the process remained difficult. Convergence greatly increases the chance of showers and thunder, and the number of storms; divergence and subsidence on any appreciable scale prevents them from forming. These features were difficult to forecast accurately. S.D.T.M. No. 94 'On an Investigation of Subsidence in the Free Atmosphere' was published during the war. It deals almost entirely with anticyclonic subsidence, but from the forecasters point of view, the most important practical problems involve the earliest stages of subsidence, including that behind cold fronts and more especially the belts of subsidence which form in unstable situations between the lines of convergence.

The upper winds and the 700 mb. charts were found to be of great value in forecasting the movement of thunderstorms and thundery rain in warm summer weather, especially when used in conjunction with the 'Sferic' reports and were also useful in assessing the movement of ordinary frontal rain from a considerable height, *e.g.*, far ahead of a warm front or behind a cold front.

Precipitation : Increased information on water content led to an improvement in forecasting rainfall, but this was very far from reaching a quantitative basis. Forecasting the amount of instability rain at one place was impracticable and, even without instability, the forecasting of rain continued to be difficult at times. Important rain areas are sometimes developed by convergence without fronts or instability, and at the end of the war the problem was still not really understood. It was pointed out in S.D.T.M. 44 on 'The Construction of Prebaratic charts' that warm front rain is closely related to the ageostrophic motion of the front. Wind soundings show up the ageostrophic motion of the lower air, but this gives an instantaneous relationship rather than a means of forecasting, which involves an assessment of future ageostrophic motion. The rainfall ahead of a warm front is increased when the cold front is close behind it, owing to convergence in the warm air and the resulting increase in its moisture content. Even in wide warm sectors there is often deep damp air within some 200 to 300 miles of the cold front and of the cyclonic centre, with a tendency for warm sector rain. It is this situation that gives prolonged rain in the hill districts in the West, often with very large 24-hour falls in the wet areas.

The difficulty of forecasting amounts of precipitation reacts on the problem of forecasting snow as distinct from rain. Unexpected snowfall on low ground is generally a consequence of its heaviness a few thousand feet up, which results in the cooling of the underlying air and eventual penetration of snow to sea level. Notes on this were given in two war-time publications, S.D.T.M. 40 and 41. Another difficulty in the British Isles is the frequency of marginal

situations. Nevertheless the increased upper air information which became available during the war certainly led to some improvement in the forecasting of snow.

Cloud : During the war there was a large increase of information about cloud structure and its relation to temperature, humidity and wind. The height of the base of low cloud was most important for aviation forecasting, but as this involves local factors it could be most effectively dealt with at local forecasting centres. The rate of rainfall is an important factor (as already mentioned, this is sometimes difficult to predict) and even moderate rainfall may soon lead to very low cloud; thus, if the rain, or its intensity or the area covered, were not foreseen, then in most cases, the low clouds were also unforeseen.

The forecasting of layer clouds such as strato-cumulus clouds was often important during the war, especially for target areas before radar methods of navigation were introduced but the knowledge gained was purely empirical and was mainly based on topographical factors. No substantial progress was made in forecasting the formation or dissipation of strato-cumulus cloud.

Considerable attention was given to the problem of forecasting the formation and dissipation of the stratus cloud associated with the movement of air over the North Sea. As with other forecasting problems, the development of genuinely quantitative methods was very difficult and in practice the forecasting of such cloud remained on a qualitative basis.

Stratus or fog is often formed by radiation over land in the night and early morning when it is absent over the sea and sometimes absent from the coastal strip, but advection of damp cool air from the sea is a necessary preliminary process. In summer there is sometimes radiation fog confined entirely to the eastern areas reached by the sea breeze. The problem is very difficult, as the depth of damp air is variable. During the sea breeze there is subsidence off the coast and dry air sometimes comes down quite low and may later spread inland. During the war special reconnaissance flights were often made over the North Sea to help in forecasting stratus, and included some temperature and humidity observations at a low level. Nevertheless the problem of obtaining adequate information about the lowest 1,500 feet of the atmosphere, which is by far the most important for forecasting stratus, was not solved.

High flying experience established the fact that in convectional cloud severe icing is liable to be experienced down to very low temperature and that this risk exists until the top of the cumulo-nimbus cloud is transformed to ice crystals; even if there is much cirriform anvil cloud there may still be supercooled drops somewhere in the interior of the anvil.

Fog : The need for accurate forecasting of fog formation became very urgent during the war because of the large numbers of aircraft in use at one time and because fog is liable to develop in just those weather situations which may otherwise be suitable for operations. It is customary to divide fog into two main types according to the cause of its formation, (*a*) advection fog formed as the result of the movement of moist air over a comparatively cold surface and (*b*) radiation fog formed on clear nights by the loss of heat from the layer next to the radiating surface, *i.e.*, the ground. In practice the separation is rarely complete, for on clear nights small scale local advection may be important and complicate the radiation process; and in the case of advective cooling a

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ground surface has often been cooled by radiation and, until fog forms or a cloud layer intervenes, the radiative cooling may still be going on whilst the advection is taking place, especially at night time.

The meteorological situation on a fairly still, clear night is probably the nearest approach in a problem of an exact treatment on physical principles; and though the problem is so complicated that recourse must be made to statistical methods, guidance may be obtained from these principles with more certainty perhaps than in many other forecasting problems. With regard to radiation fog, it had been realised for some time before the war that not only was the moisture content near the ground an important factor, but also the moisture content at levels above the surface to heights of some thousands of feet. The usual method of estimating the chance of fog formation was to assess the fall of screen temperature by one or another of various formulae, and then decide whether this fall could be sufficient to cause saturation at low levels, in which case fog would be liable to form. It was widely recognised that the 'fog-point', or the temperature at which fog forms, is 5° F. or more below the afternoon dew-point in normal conditions. Moisture is deposited as dew or hoar-frost and also diffuses upwards until the hydrolapse has become reversed. In fact a detailed consideration of the influence of the vertical distribution of water vapour on fog formation is a complicated matter, involving an assessment of radiative heat flow, turbulent diffusion of water vapour and other factors which usually oppose each other and leave a small, though all-important, residual. Nevertheless as the result of a special investigation carried out during the war a composite diagram was prepared relating the formation of fog to the vertical gradient of water vapour content (called the hydrolapse) the wind shear in the friction layer, and the depression of the dew points. The results of the investigation were published in S.D.T.M.s Nos. 38 and 52. The fog prediction diagram, which was based on a statistical analysis of past cases of fog formation, applied to the eastern half of the country where most of the bomber squadrons were based and, initially, provided an answer to the two questions 'Will fog form' and then 'Will the fog be widespread or local?' The diagram was later modified to give a broad indication of the time at which fog could be expected. The findings given in the S.D.T.M.s were useful as a guide to the local forecaster and the diagram was used, but with varying success, for the remainder of the war. In any case the investigation did direct the attention of forecasters in some quantitative way to the important influence of the hydrolapse on fog formation.

Whilst the volume of upper air information available to forecasters was vastly increased during the war by aircraft and radio soundings the data for the lowest levels were not sufficiently detailed to be of great help for quantitative assessment of the possibility of fog. Therefore, a series of soundings of the lower atmosphere by barrage balloon was begun at Cardington in July 1942. This work, which was still being continued at the end of the war, provided data both for investigation and operational purposes. Soundings of temperature, humidity and wind, were made before and during most clear nights, particularly when R.A.F. operations were planned and in progress, and the data telephoned to the Central Forecasting Office where it gave considerable assistance to the forecaster.

The influence of several other factors affecting fog formation became more clearly recognised, only the chief of which will be discussed here.

Investigation showed that a very deep moist layer does not necessarily favour the formation of radiation fog; indeed it may tend to prevent fog because it reduces the outflow of radiant energy, radiation from the water vapour itself being of secondary importance. On the other hand pronounced dryness aloft, which in itself increases the radiation outflow, is usually due to subsidence and the consequent warmth of the air will reduce the radiation loss. Which factor will be most important will vary with every occasion. It appeared that the moisture content above about 2,000 feet may not in general influence fog formation either way, and that the formation is largely determined by the moisture below this level; if, however, a moist layer is much less than 1,000 feet deep, as it may be when subsidence penetrates far down, then any fog that forms tends to be patchy in character, and to occur in low lying areas leaving the higher ground clear; fog which at the begining of the foggy period is widespread may degenerate into a patchy fog for this reason; nevertheless this fog where it does form may be even more intense than in the case of widespread fog.

The importance of the thermal properties of the ground and the degree of wetness have been stressed. The thermal properties that are important are its heat capacity per unit volume and its conductivity, both of which are characteristic of the soil itself and both of which are markedly altered by the wetness of the soil. Broadly speaking, low heat capacity and low conductivity favour fog formation. In the British Isles the degree of wetness of the ground is more important in late spring and summer than in autumn and winter and early spring because in the latter seasons the ground, for hygrometric purposes, is saturated or almost so, and the addition of further rain may, in fact, reduce the risk of fog by increasing the heat capacity and conductivity of the soil. Evidence that fog tends to occur more readily over water-logged ground is probably an example of two effects of the same cause, in that in just those low lying regions where water accumulates, shelter is often afforded to the air so that turbulent mixing through a deep layer is prevented and the cooling concentrated in a shallow surface layer and, in valleys particularly, this may be reinforced by katabatic effects.

The investigations referred to above indicated that the distribution of temperature in the ground has an appreciable influence on the behaviour of the screen temperature, and is therefore a factor in fog formation, on clear nights. Some, though not conclusive, evidence was adduced to show that the risk of fog in areas of county size partly depends on the degree of cultivation in the area, arable land being less liable to fog when the land is bare in winter.

The investigations did not explain the way in which the intense smoke pollution in industrial areas increases the risk of fog, as it almost certainly appears to do. It is realised that smoke particles are not the nuclei on which water condenses. The presence of smoke particles cannot, of course, increase the net rate at which radiant energy is leaving the lower layers; indeed, a smoke layer helps to distribute the cooling through a deeper layer and from this point of view militates against fog formation, which requires the cooling to be concentrated in a shallow layer near the surface. Calculation shows that the reduction in a given intensity of illumination due to the smoke particles themselves is not great, even in the centre of an industrial city. Nor does the explanation lie in the assumption that the smoke particles, though not themselves nuclei, are associated with nuclei, for supersaturation is not observed

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in country areas, the implication being therefore that there are always sufficient nuclei present even in country districts. Again, since fog does not occur in industrial areas at humidities noticeably below saturation, the smoke particles cannot be associated with markedly hygroscopic nuclei. The precise nature of the influence of smoke pollution had still to be discovered.

It has been advanced by some authorities that a frozen or snow covered ground tends to prevent fog formation because of the excess saturation vapour pressure over water as compared with ice. It may be argued that this is unsound ; indeed, in conditions of frozen or snow covered ground some of the thickest fogs are experienced in the United Kingdom. In any case so far as the British Isles are concerned, the effect is of little importance and the forecasting of fog formation during the war was not influenced by this hypothesis.

The problem of forecasting accurately the formation of advection fog can only be attacked quantitatively when there are available measurements of soil temperature over a large network of stations. At the beginning of the war such data was almost non-existent. A note written in 1942 (S.D.T.M. No. 59) drew attention to the importance of the exchange of heat between the air and the ground in certain situations, and in consequence the Meteorological Research Committee in 1943 recommended the installation of earth thermometers at a large number of aerodromes to assist in the forecasting of advection fog. Unfortunately, the war-time shortage of thermometers prevented this, but thermometers were installed at Dunstable and Cardington. The data proved of value for forecasting and investigation.

Code Forms and Specifications

Meteorological reports are normally transmitted in code forms made up of 5-figure groups. Standard code forms were laid down before the war by the International Meteorological Organisation (I.M.O.) ;[1] the codes had no security significance but served to condense the information for speed and economy in transmission and to avoid language difficulties in international exchanges. There were a number of code forms for different purposes, each distinguished by an internationally recognised word, *e.g.*, SYNOP for synoptic report, SHIP for ship's report, TEMP for temperature report, etc. In discussing codes it is convenient to use their ' symbolic forms ' which are made up of letters for easy reference ; in actual reports the letters are replaced by figures, the figures used depending on the value of the meteorological item being reported. For example, the symbolic form F.11 of one of the standard international codes for surface reports was : III C_L C_M ww VhN_h DDFWN PPPTT UC_Happ. In actual reports, the letters were replaced by figures as follows :—

III replaced by Station Index Number of three figures.
C_L replaced by one figure indicating the type of low cloud.
C_M replaced by one figure indicating the type of medium cloud.
ww replaced by two figures indicating the type of the present weather.
V replaced by one figure indicating visibility.
h replaced by one figure indicating cloud height.
N_h replaced by one figure indicating amount of cloud height.
DD replaced by two figures indicating wind direction.
F replaced by one figure indicating wind force.
W replaced by one figure indicating past weather.

[1] *See* I.M.O. Publication No. 9.

N replaced by one figure indicating total amount of cloud.
PPP replaced by three figures indicating atmospheric pressure.
TT replaced by two figures indicating air temperature.
U replaced by one figure indicating relative humidity.
C_H replaced by one figure indicating type of high cloud.
a replaced by one figure indicating characteristic of pressure tendency.
pp replaced by two figures indicating amount of rise or fall of pressure.

The specifications of the figures were determined by international convention, *e.g.*, for type of low cloud, figure 1 indicated fair weather cumulus, 2 indicated large cumulus and 6 ragged low clouds of bad weather, etc.

Surface Observations

Surface observations at the outbreak of the war were reported in the standard International forms as given in I.M.O. Publication No. 9, 1937. The changes introduced during the war by the Meteorological Office were all designed to give greater precision.[1]

It was soon found that the reporting of cloud height by means of one figure was not precise enough for the meteorological requirements of operational flying. Code figure 3, for instance, applied to any cloud base in the important height range of 600 to 1,000 feet. To give additional detail in respect of cloud base, two figures were prefixed to the normal coded report whenever cloud height was below 5,000 feet. These figures gave the cloud height in hundreds of feet when the height was measured ; when heights were estimated they were given to the nearest 100 feet below 1,000 feet, to the nearest 200 feet for heights between 1,000 and 2,000 feet and to the nearest 500 feet between 2,000 and 5,000 feet.

In August 1940, to facilitate identification of the rapidly increasing number of reporting stations, each station was allotted a 3-letter index group (ABC) in addition to its 3-figure index number *e.g.*, ELM = Elmdon : PLY = Plymouth. At the same time, in addition to the reporting of the main cloud base in hundreds of feet ($h_l h_l$) whenever it was 8,000 feet or below, the height (h in the preliminary figure group) of any low cloud fragments was included. At coastal stations the state of the sea (S) and visibility seawards (V_s) were also reported hourly. The word VIS I. which had been previously reported at the end of a message, whenever visibility was four miles,[2] became part of the preliminary letter group when appropriate. The standard reporting code at that time was expressed symbolically as :—

ABCI $h_l h_l hSV_s$ $IIIC_LC_M$ $wwVhN_h$ DDFWN PPPTT UC_Happ.

Later in 1940 and 1941 another letter (G) was added to the preliminary letter group (i) for reporting weather phenomena dangerous to Balloon Barrages and (ii) for reporting visibility in tens of yards whenever it was 2,200 yards or less.

The prediction of fog was very important, and for this purpose consideration of the dew point temperature of the air was essential. Until October 1941, dew points plotted on the weather charts used by forecasters were approximate only, the value being obtained from the coded values of dry bulb temperature (TT)

[1] S.I. 22.

[2] The code figure 6 in the international visibility code covered a wide range of visibilities, viz, 4,400 yards to 6¼ miles. To subdivide this range, and give a closer indication of the observed visibility, ' VIS I.' was added to the report if an object could be seen at 4 miles.

and relative humidity (U). With $TT = 60°$ F. and $U = 8$ (80 per cent to 89 per cent) the mean value, 55° F., for the dew point temperature (T_sT_s) was plotted. The actual dew point of air with a dry bulb temperature of 60 degrees is 53° F. if relative humidity is 80 per cent and 56° F. if relative humidity is 89 per cent. The few degrees involved could be vital in fog prediction and from 15 October 1941, the second figure of the dew point temperature was reported instead of state of sea at synoptic hours.

The two preliminary groups thus became :—

ABCIG $h_lh_lhT_sV_s$ at synoptic hours.

ABCIG $h_lh_lhSV_s$ at non-synoptic hours.

To provide for a single figure expressing broadly the weather fitness for aviation, a Weather Fitness Number (F_n) was introduced in May 1942. It was computed from the meteorological elements affecting aircraft landings, allowance being made for the hours of darkness and also for local obstructions, such as hangars, wireless masts or near-by hills in their effect on the practicable amount of clear space below the cloud base.[1] 0 represented the worst, and 9 the best, conditions. To enable recipients to identify this figure quickly, F_n was reported at each hour of observation as the first figure of the preliminary figure group: the first occasion of a 6-figure group in British synoptic reports. From July 1942, an Airfield Fitness Number (F_g) was also reported; this referred to the state of the ground. The value of this figure depended at first on other than meteorological factors, but in October of the same year it was changed to take account only of conditions arising from meteorological causes. It was reported by inland stations (which did not report visibility seawards) as the sixth figure of the preliminary group which became :—

$F_nh_lh_lhT_sF_g$ at synoptic hours.

$F_nh_lh_lh$—F at non-synoptic hours

Coastal stations reported F_g only when it was poor, as the fifth letter of the preliminary letter group.

Codes for reporting surface observations then remained practically unchanged except in detail until December 1943, when the preliminary groups were re-cast completely, but the basic International Form F.11 was unchanged except for substituting the dew point temperature (T_sT_s) in place of relative humidity (U). The resulting 6-figure group $T_sT_sC_H$ app was adapted for re-issue by wireless telegraphy by coding barometric pressure (PPP) to the nearest millibar (PP) *i.e.*, by omitting tenths, and transferring the first figure of dew point temperature (T_sT_s) to the previous group.

Other important changes were the introduction of :—

(*a*) Two figures for reporting visibility in tens of yards up to 100 yards, in hundreds of yards up to 4,000 yards and in miles when above 4,000 yards.

(*b*) Two figures for reporting height of the lowest cloud in hundreds of feet (in thousands of feet if above 8,000 feet).

(*c*) A separate figure for reporting the height of the 'next lowest' cloud.

(*d*) Separate figures for reporting the amounts of the lowest and 'next lowest' cloud.

and the omission of the preliminary letter group.

[1] Synoptic Instruction No. 76.

The new standard forms, given below, were numbered with an asterisk in accordance with a recommendation of the Combined Meteorological Committee, Washington.

F*143 $F_gF_nVVV_sS$ $h_lh_lN_lh_2N_2$ $IIIC_LC_M$ $wwVhN_h$ DDFWN PPPTT $T_sT_sC_H$ app

F*110 $IIIC_LC_M$ $wwVhN_h$ DDFWN $PPPTT_s$ T_sC_H app

Reports from mobile meteorological stations with the Allied Expeditionary Force were made in code F*110 but with the first group $IIIC_LC_M$ replaced by $9L_tL_tl_tl_t$ or $4_tL_tL_tl_tl_t$. The initial figure 9 or 4 had a significance depending on the theatre in which the mobile station was operating and L_tL_t and l_tl_t were the last two figures of latitude and longitude respectively in degrees and tenths.

Upper Air Observations

The results of pilot balloon observations continued to be reported in International Code F.331 (as given in I.M.O. Publication No. 9) until 1 December 1943. From that date heights were reported in thousands of feet instead of hundreds of metres while wind speeds were given in knots in order to facilitate the application of the reports to the requirements of air navigation.

Radio-sonde reports of upper winds were at first coded in a modified form of Code F.331.[1] To assist in the interpretation of the reports, tables were issued giving mean heights of the standard pressure levels for which wind direction and speed were reported and, in June 1941, provision was made for a 'tolerance' figure to be included indicating the probable degree of accuracy of each wind measurement. Some radio-sonde reports later included temperature and relative humidity observations in addition to wind direction and speed. From December 1941, the various reports were given indicator words and appropriate code forms, viz :—

Indicator	*Type of report*
PRAW	Upper winds only.
PRAWT	Upper winds, temperature and humidity.
PRAT	Temperature and humidity but not wind.

From 1 December 1943, upper winds in PRAW and PRAWT reports were given in knots instead of in kilometres per hour. At the same time the codes were modified to facilitate reporting values for significant points in the ascent *i.e.*, other than at the standard pressure levels. In June 1944, provision was made for reporting the height above MSL in tens of feet of the 750, 500 and 300 mb. levels in PRAT and PRAWT messages. This was modified in January 1945 by the reporting of the heights of the 1,000, 900, 800 and 700, etc., mb. isobaric surfaces. Details of the final codes are given in Appendix I to I.M.O. Publication No. 9, Fascicule 1, Third edition, 1946.

Observations from Aircraft

At the beginning of the war reports of upper air temperatures from meteorological reconnaissance aircraft were received in the THUM code which had been in use in the British Isles for some years, and which remained in use until 15 November 1941 for reporting observations at 50 mb. intervals during vertical ascents over the land. It was then replaced by the General Code for Meteorological Observations from Aircraft, introduced to diminish the number of codes in use.

[1] *See* I.M.O. Publication No. 9, Fascicule 1, Third edition and S.I. 117.

Observations made during high altitude aircraft ascents to about 40,000 feet, which began in the autumn of 1941, were reported in a special PRATA code.[1] A new code was devised in January 1941 for meteorological reports from reconnaissance aircraft. It was modified from time to time in the light of experience and, from November 1941, was used for all reports from aircraft with the exception of those from transatlantic flights and the PRATA reports referred to above. In August 1945 a revised code for aircraft weather reports, known as CAW-C was introduced. Details are given in Appendix I to I.M.O. Publication No. 9, Fascicule 1, Third edition, 1946.[2]

Before the war occasional reports from aircraft of wind, weather and clouds were received in plain language. They were known as PLOB reports and increased considerably in number after the outbreak of war.[3] These reports were extremely valuable, especially when they referred to conditions over enemy or enemy-occupied country. From March 1941, they were distributed by teleprinter partly in code and partly in semi-plain abbreviated language. This avoided the name of the airfield of origin appearing in the reports and also reduced the length of the message. Later in the year they were reported in the General Code for Meteorological Observations from Aircraft referred to above and from November 1943 were preceded by ' confidence ' letters.

Special aircraft ascents were being made by the R.A.F. in 1940 to obtain details of height, thickness and amount of cloud in S.E. England. These were reported in a special ' SEBUN ' code.

From July 1941, crews of aircraft delivered across the Atlantic kept a meteorological log. Reports derived from these logs were coded as FERAT reports. Similar reports from crews of American ferry and delivery aircraft were made available from October 1943 as FERATUS reports.[4]

Reports of the height of base and top of clouds were received from aircraft in a special CLOBAS (CLOTOP) code—*see* A.M.O. A.370/44. Codes for the supply of in-flight reports, REOB and FERIMET, have already been mentioned elsewhere.[5]

Analyses

The code which was eventually developed for the supply of current and predicted analyses was the Combined Analysis Code, which was produced as the result of the deliberations of the Combined Meteorological Committee in Washington and was brought into use in August 1944. Details have been published in I.M.O. Publication No. 9, Fascicule 1, 1946.

Miscellaneous

During the war a number of codes were devised for the supply of reports and forecasts to aircraft in flight and for the exchange of similar advisory information between meteorological offices. At the end of the war, UCO was in almost general use for giving information to aircraft in flight and the M.O.O.F. code for the exchange of advisory route and landing forecasts. Details of these codes are also given in I.M.O. Publication No. 9, Fascicule 1, 1946.

Weather reports from personnel engaged in other than meteorological work, such as the Royal Observer Corps and certain Balloon Barrages, were made in code form.[6]

[1] S.D.I. S.36 and S.I.117. [2] S.D.I. S.61 and S.I.156.
[3] S.D.I. 61. [4] S.I. 6. [5] S.I. 134. [6] S.D.I. 54.

CHAPTER 30

THE METEOROLOGICAL RESEARCH COMMITTEE AND THE JOINT METEOROLOGICAL RADIO PROPAGATION SUB-COMMITTEE

The Meteorological Research Committee

Formation and Policy of the Committee

The formation of a Meteorological Research Committee was considered in 1939, but the project was dropped on the outbreak of war. An assistant Director (A.D.M.O.III) remained charged with handling research problems and war-time technical investigations, and attended meetings of the Aeronautical Research Committee (A.R.C.) and its Sub-Committee for Meteorology, on behalf of D.M.O.[1]

In 1940, the A.R.C. raised the problem of condensation trails made by aircraft at great heights. Since these trails enabled the enemy to detect aircraft it became important to discover the exact conditions for their occurrence and the means, if possible, of avoiding making the trails. The physics of the problem was solved by Dr. Dobson and Dr. Goldie, more or less independently, the latter showing that for each level there was a temperature above which there was immunity from trail-making from the exhaust. High altitude flights made early in 1941 at Boscombe Down proved these results. Thus, on any given date, there was a minimum level at which liability to trails began. This was afterwards termed the Mintra level and an estimate of its value was included in the weather forecasts. This problem of contrails emphasised the need for an accurate means of measuring humidity at very low temperatures.

Interest in the problem of fog dispersal by artificial means was revived in the summer of 1941 and in October, A.D.M.O. III prepared for the A.R.C. a summary of the theory and experiments made in the United States.

In 1941, partly as a result of pressure from the naval authorities, preliminary inquiry was made into the possibility of long range weather forecasting.

In 1941, The numerous problems arising led certain prominent scientists to offer to serve in an honorary capacity, as a war-time measure, on a Meteorological Research Committee, and the Secretary of State for Air formally constituted such a Committee in September, with the following members :—

Professor S. Chapman, M.A., D.Sc., F.R.S. (Chairman).
Professor D. Brunt, M.A., Sc.D., F.R.S.
Mr. G. M. B. Dobson, M.A., D.Sc., F.R.S. (later Vice-Chairman).
Professor Sir Geoffrey Taylor, M.A., F.R.S.
The Director of the Meteorological Office.

[1] A.M. File 854507/38.

The Director of the Naval Meteorological Service.
The Director of Scientific Research, Ministry of Aircraft Production.
A representative of the Air Staff.
A representative of the Director-General of Civil Aviation.
(Sir Charles Normand, D.Sc., was added to the Committee in 1945.)

The terms of reference were as follows :—

(*a*) To advise the Secretary of State for Air as to the general lines along which meteorological research should be developed.

(*b*) To advise and assist in the carrying out of investigations and research within the Meteorological Office.

(*c*) To receive reports upon meteorological investigations carried out in the Meteorological Office or on behalf of the Air Ministry, and to make recommendations for further action.

(*d*) To co-ordinate the investigations undertaken in the Meteorological Office with related activities carried out elsewhere, both in this country and abroad.

(*e*) To make an annual report to the Secretary of State for Air.

The Committee met 34 times between September 1941 and August 1945. Sub-Committees appointed to deal with special questions also met a number of times. By courtesy of the Royal Aeronautical Society, the meetings of the main Committee were mostly held in the Society's rooms.

When the Meteorological Research Committee was formed, the Aeronautical Research Committee decided to abolish its Meteorological Sub-Committee and to refer all meteorological problems to the Meteorological Research Committee. Since then, the Meteorological Research Committee has sent a half-yearly report to the Aeronautical Research Committee, in order to keep the latter informed of developments in meteorological research.

The Meteorological Research Committee devoted its attention during the war mostly to problems of direct importance to the war effort, and concentrated upon investigations in which advances might reasonably be hoped for in a relatively short time. In the programme of research, which was revised annually, these considerations largely dictated the priorities allotted to the various items. At the same time, the Committee obtained the co-operation of the Royal Society and arrangements were made for a comprehensive investigation into various aspects of the problem of radiative equilibrium in the atmosphere. The Royal Society entrusted the supervision of this work to the Gassiot Committee. Many of the practical investigations which were undertaken demanded the use of aircraft, and arrangements were made for a number of aircraft and personnel to be added to the High Altitude Flight at the Aeroplane and Armament Experimental Establishment, Boscombe Down, specifically for work on behalf of the Meteorological Research Committee.

Investigations

Reports : The Committee considered 240 reports and memoranda covering a wide field, during the war. Reports for the Committee were issued in a series numbered M.R.P. . A similar series of J.M.R.P.s contained reports for the Joint Meteorological Radio Propagation Sub-Committee. A list of Meteorological Research Committee papers up to August 1945 is given in M.R.P. 101, 152, 201 and 251.

Development of Meteorological Instruments : The problem of determining air temperatures accurately from aircraft was solved when a considerably improved type of thermometer (a distant reading electrical resistance thermometer using a balanced bridge) was developed for meteorological use, largely as a result of experimental flights at Boscombe Down.

An important series of experiments was made to determine the corrections which must be applied to the readings of aircraft thermometers to allow for heating due to the speed of the aircraft. These corrections became known with considerable accuracy and air temperatures could be determined with substantially higher precision than before.

Great progress was made in measuring the humidity of the air at very low temperatures. Three methods were tried. In the first, the hoar-frost point was measured by a special form of hygrometer, one of which, designed by Dr. Dobson in association with Mr. Brewer, proved to be an accurate instrument, suitable for fundamental observations and scientific investigations. Considerable numbers of these hygrometers were produced and specimens were lent to other countries. The second main method involved measuring the electrical resistance of a hygroscopic film containing lithium chloride, but practical difficulties were met in making the instrument suitable for use in aircraft. An alternative form of instrument measured the changes in thickness of such a film by optical means. Neither of these devices advanced to the production stage. The third type of hygrometer under investigation was intended for routine use on the meteorological reconnaissance aircraft. The sensitive element in this instrument was gold-beater skin, whose physical characteristics, particularly lag and hysteresis, had been examined. This instrument showed much less promise than the frost point hygrometer.

To determine the meteorological conditions at heights beyond those attainable by aircraft, radio-sondes were used in large numbers. The British design of this instrument was brought up to a high standard in so far as the measurements of temperature were involved, and, later, in collaboration with the trade, the design was adopted for mass production.

Progress made in predicting and dispersing fog raised the need for more exact methods of measuring visibility at night and for devices which would give warning when visibility fell below a specified distance. Forms of apparatus using fixed lights and photo-electrical cells were developed in an extensive series of experiments by Dr. W. R. G. Atkins, F.R.S.

For a number of years it had been customary to make the rapid determination of cloud height at night by means of a small searchlight pointed vertically and a simple alidade for measuring the angular elevation of the spot where the light strikes the cloud. A portable form of this equipment, suitable for use by the mobile units of an expeditionary force, was successfully developed.

Attempts to determine the thickness of cloud by the loss in the daylight illumination reaching ground level were tried but could not be made to yield the required information in a definite way.

The measurement of upper winds by radio direction finding methods made great progress. Shortly before the outbreak of war, the Meteorological Office set up a station for that purpose. Four such stations were later brought into operation in the United Kingdom. The method was effective up to heights far

beyond those attainable by aircraft and could be used in all weather conditions; It proved to be very accurate and the data obtained were of the utmost value, not only for forecasting but more directly for the long distance navigation of aircraft and in other military problems. The method, however, required a relatively large number of personnel and involved a somewhat elaborate and immobile layout of ground equipment. Attention was, therefore, turned to adapting radar equipment to wind measurement or, alternatively, to using a 'radio theodolite' in conjunction with a special transmitter carried out on a sounding balloon. The radar method quickly reached the stage of development which enabled it to be used under field conditions for giving the wind up to a height of about 50,000 feet. The design of a 'radio theodolite' was started and showed promise.

Short Range Forecasting: The method of predicting fog formation, by taking account of the degree of atmospheric turbulence and of the gradient of water vapour in the lowest thousand feet of the atmosphere was further developed to give the time of formation of fog.

The analysis of upper air data in connection with routine weather forecasting made very considerable strides. In this matter, the Office was indebted to Dr. S. Petterssen for substantial theoretical and practical contributions. The routine study of changes in the atmosphere by means of upper level charts in addition to the ordinary level chart proved of great value and the method promises to be one of the most important developments in forecasting technique.

Under the guidance of Dr. G. M. B. Dobson, the investigations into the variation of the ozone content of the upper atmosphere were continued at a network of stations in the British Isles and the bearing of anomalous distributions of ozone upon the weather situation was still under consideration at the end of the war.

Long Range Forecasting: Investigators in various countries have from time to time claimed to have devised successful methods of forecasting weather for periods of a week to a month ahead. Whilst the Committee were not satisfied as to the theoretical soundness of any of these claims, the possible practicable value of even an empirical method of long range forecasting could not be ignored and it was decided to test by practical trial the Weickmann method of pressure wave analysis, which appeared to offer the greatest prospect of success. A six months' full scale trial was accordingly made. A full and critical examination of the results indicated that the method does not possess the degree of reliability hoped for. A modified method of pressure wave analysis was also tried, but again without success.

Sir Gilbert Walker made a statistical investigation into the relationship between Arctic conditions and subsequent European weather. Although a small degree of relation was shown, the correlations found were too small to be of significant value in seasonal forecasting.

Aviation Problems: The Meteorological Research Committee followed the work of the Petroleum Warfare Department on the artificial dispersal of fog from airfields. This work covered a series of field experiments at Staines using line sources of heat under selected and carefully recorded conditions of wind, temperature and humidity; a series of model experiments at Earl's Court designed to elucidate the heat distribution; an examination of the

experience accumulated at airfields equipped with 'Fido'; and a considerable range of instrumental work on the free water content of the air and the water-drop size distribution in fogs of different intensities. Meteorological advice was given in regard to the layouts and heat outputs for fog dispersal installations at various airfields, following upon analysis of wind velocities accompanying fogs and the topography of these airfields.

The study of ice-accretion upon aircraft was pursued. An instrument for measuring the number and size of droplets in clouds was completed and systematic determinations were made in clouds of various types and under various meteorological conditions.

At the request of the Aeronautical Research Committee, attention was directed to the problem of gustiness in the upper air in relation to the strength of aircraft construction. Reports upon existing information were submitted and attempts were made to obtain additional experimental information upon the maximum gusts liable to be encountered by aircraft. Estimates of the maximum upward speeds were worked out theoretically from rates of rainfall and sizes of hailstones.

The dense and persistent type of condensation trail produced by the exhaust of aircraft engines had already been mentioned. Primarily, the phenomenon depends on air temperature but below a certain temperature at any given height, the occurrence was believed to depend on humidity of the air. This was verified by means of the hygrometers referred to above. It was also found that, in special conditions of supersaturation of the atmosphere, dense, persistent trails of aerodynamic origin may be formed from the wing and propeller tips of certain aircraft.

A new problem involving rather similar principles presented itself in 1944, namely, the detection of U-boats using the *Schnorkel* device. A report was prepared on the condensation of the exhaust of Diesel engines and on the meteorological conditions under which there is the best chance of the exhaust becoming detectable.

Exploration of the Stratosphere: It had been known for some years that when an aircraft enters the stratosphere, any condensation trails of the long persistent type, which it may have been making, usually give way to short ephemeral trails. Theoretical considerations pointed to a relatively low humidity as the probable explanation. The development of the Dobson-Brewer hygrometer made it possible to measure humidity at the temperatures involved and a Fortress aircraft made a number of flights into the stratosphere at Boscombe Down. On each such flight, a sudden and very large drop in humidity was found on entering the stratosphere—a drop in most cases to an astonishingly low value. The flights were made on occasions when the stratosphere was lower than usual and it remains to be discovered whether such conditions exist when the stratosphere is higher. Possible physical explanations of this astonishing dryness were considered. In particular, if air from a height of some ten miles above the equator (the coldest known part of the atmosphere, where temperatures can be as low as −90° C.) were transported to temperate latitudes, and if in the course of its journey it also subsided to a height of about five miles, its temperature and humidity could agree approximately with the conditions discovered. According to this theory, the extreme dryness should be a feature of the rather low stratosphere such as are found above depressions in temperate latitudes, though all stratosphere would

be relatively dry in temperate latitudes and only those near the equator would approach saturation. It is thus possible that the observations may lead to an extension of knowledge of the world atmospheric circulation at great heights and of the larger scale physical processes of weather.

A hyper-velocity gun of the Royal Marine Siege Regiment, which could fire shells to a height of about 100,000 feet, presented another means of exploring the atmosphere to heights far beyond those attainable by aircraft.[1] Some smoke shells fused to burst at that height were produced and, by using Flash-Spotting posts, the drift of smoke from the shell bursts was used to measure the wind speed and direction at 100,000 feet. The results showed that the wind at those great heights is easterly from about May to August inclusive and westerly for the rest of the year. The general nature of this result had been deduced from observations made during the 1914–18 war on the sound of explosions, but it had not been possible to obtain direct measurement. A further investigation depended on recording by microphones the length of time needed for the sound of a shell burst to reach the ground. If the height of burst can be measured by radar, it should then be possible to calculate the temperature of the atmosphere at heights beyond those attainable by other methods of observation.[2]

The increasing wealth of upper air data led to a number of investigations into the larger scale physical processes of weather. Important investigations on the subsidence of air by Dr. S. Petterssen have already been mentioned. A member of the Meteorological Office staff also made a provisional investigation on the vertical circulations of the atmosphere in cyclones and anticyclones. Such investigations may point the way to improved and possibly simplified methods of applying upper air information to the problem of forecasting weather.

Anomalous Propagation or Radio Transmissions: The anomalous propagation of short wave signals led to a demand for very detailed information about the variation of temperature and humidity in the lowest thousand feet of the atmosphere. In order to assist in this work, instruments were erected for the automatic recording of temperature and humidity at heights of 4, 50, 155 and 350 feet on a radio tower at Rye. Low level humidity and temperature profiles, giving a detailed structure not hitherto available, were obtained in the Irish Sea under various synoptic conditions between July and October 1944. Aircraft and balloon-flying trawlers co-operated in this enterprise.

Agricultural Meteorology: The Agricultural Research Council sent the Meteorological Research Committee in 1944 a memorandum by the Director of Kew Gardens, indicating a number of directions in which agriculturists needed new and more precise meteorological data. The Committee held a special meeting, attended by the Director of Kew Gardens, the secretary of the Agricultural Research Council and other experts. After discussing fully the special needs of agriculturists, action was agreed upon for providing this information so far as possible.

Collaboration with Government Departments, the Dominions and Allies

Government Departments, Universities and other institutions were notified early of the formation of the Meteorological Research Committee in order to

[1] A.M. File S.100882. [2] A.M. File S.102247.

co-ordinate the committee's work with meteorological investigations elsewhere. Similar action was taken in regard to the Dominions. Close liaison was established with the Allies' meteorological organisations. Research programmes were exchanged with the Combined Meteorological Committee in Washington, and selected reports by the Meteorological Research Committee were sent, after approval, to the United States, Russia, Canada, Australia, New Zealand, South Africa and India.

The Colonial Research Committee asked for suggestions as to research on meteorological problems in the colonies and were recommended to set up stations for investigating upper air conditions at 18 places in the equatorial colonies. Data thus derived would be of value to flying on the Imperial Air Routes and in the scientific study of the meteorology of equatorial regions.

Joint Meteorological Radio Propagation Sub-Committee

Origin and Organisation

The Meteorological Office received a number of requests in late 1942 and early 1943 for data from investigators in the field of radio, many of whom were meeting meteorological problems. The Meteorological Research Committee considered the position at a meeting on 23 February 1943, attended by the Chairman of the Ultra Short-Wave Propagation Panel and a number of radio research workers from official establishments, and decided to appoint a Sub-Committee to co-ordinate requests for special meteorological observations in connection with radio investigations. The Chairman of the Ultra Short-Wave Propagation Panel and D.M.O. were to nominate representatives of the Panel and the Meteorological Office respectively, the interests of all three Services being represented.[1] It was later agreed that the Sub-Committee should consist of D.M.O. (Chairman), and representatives of the Telecommunications Research Establishment, the Admiralty Signals Establishment, the National Physical Laboratory (Radio Dept.), the Army Operational Research Group, the Meteorological Office and the Naval Meteorological Service. At the request of the Director-General of Signals (Air Ministry), a representative of the Baddow Research Station was later added to the Sub-Committee.

The functions of the Sub-Committee were more clearly defined in February 1944, and the Chairman of the Ultra Short-Wave Propagation Panel, the Ministry of Supply and D.M.O. agreed on the following terms of reference:—

(*a*) To advise on the meteorological observations required for correlation with radio data.
(*b*) To examine the origin and characteristics of the special meteorological conditions which affect the refractive index of the atmosphere with respect to radio waves.
(*c*) To consider the forecasting of the special types of meteorological conditions specified in (*b*).
(*d*) To consider the meteorological aspects of any other radio meteorological problems referred to the Sub-Committee by the Meteorological Research Panel.

These terms of reference remain applicable.

[1] M.R.P. 174, 217, 283.

At the time of its formation, the Sub-Committee was named 'The S/W Radio Meteorological Sub-Committee.' This was changed to the present title when the terms of reference were redefined.

The Sub-Committee first met on 21 June 1943. By 15 August 1945, it had met 14 times and considered some 60 reports or papers.[1]

The Principal Problems

The principal problems considered by the Sub-Committee can be divided into three classes, viz. :—

(*a*) Problems of anomalous propagation in the British Isles.

(*b*) The production of radar echoes by meteorological phenomena.

(*c*) The relation of the climatology of various parts of the world to the conditions of propagation of radio waves.

The work done on these problems is outlined below.

Anomalous Propagation : The refractive index of the atmosphere with regard to short (*i.e.*, less than about 5 metres) radio waves depends upon the pressure, temperature and humidity of the air; as these three quantities normally vary with height, it can be shown that a radio ray which is initially nearly horizontal may suffer appreciable bending. The practical effect of this is that a radar or radio equipment which is used primarily for detection of surface targets or for communication between two points at the same height above M.S.L. will have effective ranges which will be dependent on meteorological conditions. The term 'anomalous propagation' came into use to indicate occasions when the range of a radar or radio equipment is greater than normal.

A fair amount of information was available in 1943 about the variation of temperature and pressure with height in the layers of the atmosphere, but little was known about the variation of humidity. To remedy this, continuous records of temperature and humidity at various heights on a lattice tower at Rye were kept from September 1943.

Between July 1943 and September 1945, the N.P.L. experimented on the transmission of ultra short radio waves across Cardigan Bay and from a coastal site in North Pembrokeshire to a station in Wigtownshire. These transmissions were designed to throw light on the effect of meteorological conditions on the propagation of the radio waves. The Meteorological Office arranged for simultaneous observations from aircraft of temperature and humidity at various levels in the air, and the Naval Meteorological Service for observations from trawlers in Cardigan Bay.

The Telecommunications Research Establishment (M.A.P.) investigated the effects of meteorological factors on radar transmission on ultra short wave bands at Llandudno in August/September 1944. Aircraft were allocated to make low level observations of temperature and humidity over the path of the transmissions.

The range of coastal radar equipment was a matter of operational importance in 1943 and although understanding of this phenomenon of anomalous propagation was then very limited, the Meteorological Office attempted to forecast whether radar ranges would be normal or greater than normal for coastal areas off the east and south coasts of England. The attempt was dictated by operational necessity and in view of the then very limited knowledge of the subject was not completely successful.

[1] A list of those published during the war is given at Appendix 25.

Radar Detection of Clouds and Precipitation : It was known by the beginning of 1945 that some radar equipments could detect clouds and/or precipitation under certain conditions. A meteorological officer was attached to R.A.F. Station, Sopley (a radar station), in March/April 1945 to investigate this phenomenon. His report, and those received from other parts of the world showed that, potentially, radar used to locate clouds and/or precipitation is a powerful meteorological instrument.

Conditions Overseas : Although knowledge of the exact effect of meteorological conditions on radio propagation was too limited to allow prediction of how much the range of a radio set would be increased by specified meteorological conditions, the type of conditions leading to increased ranges was known fairly certainly. To meet the needs of those planning operations against Japan, many areas in the Far East were examined from the climatological angle and the probability of anomalous propagation assessed.

Co-operation Outside the British Isles

The chairman and some members of the U.S.A. Committee for co-ordinating research on ultra short-wave propagation in America attended the 4th meeting of the Sub-Committee and reports and minutes were later exchanged regularly between the Sub-Committee and the U.S.A. Committee. Collaboration was also maintained with the Dominions.

CHAPTER 31

INVESTIGATIONS AND PROVISION OF CLIMATOLOGICAL DATA FOR PLANNING

Pre-War Arrangements

Before the war, information for the planning of possible military operations was usually supplied in response to specific inquiries. The method of reply and the allocation of responsibility was then governed by the Meteorological Office Orders dealing with inquiries, under which inquiries for general climatological information were assigned to the Climatological Division, but those which concerned the Navy, Army or Aviation, whether climatological or not, were referred to the appropriate Division for Naval Services, Army Services or for Aviation, Military or Civil.[1]

As a result of this procedure in regard to aviation inquiries, a considerable amount of rather specialised climatic data was accumulated, in the Aviation Service Division, from which, with the co-operation of the Climatological Division, a series of reports had been begun in 1932 on the climatic conditions on the main civil air routes (The Aviation Meteorological Reports M.O.M. 365).[2]

The Army inquiries were usually for Military Intelligence Summaries, the answers to which were expected to be on a very stereotyped pattern. The Army, however, required for their defensive planning the answers to questions on wind structure in relation to chemical warfare, and the development of a high degree of accuracy in calculating Artillery Meteor reports. Much work was done on these problems by the meteorological offices at Porton, Shoeburyness and Larkhill.

In October 1931, the Admiralty requested a series of handbooks on climatology for various oceans and sea areas. The Naval Services Division and the Climatological Division of the Meteorological Office collaborated in working on the first of these handbooks, The Handbook of Weather in the Mediterranean, which was produced in parts between 1935 and 1939. After the Naval Services Division had become a separate entity, as the Directorate of Naval Meteorological Services, Admiralty, in 1937, the programme of producing climatological handbooks of the oceans was continued in the Climatological Division at the request and with the co-operation of the Director of Naval Meteorological Services.[3]

The evidence given before the Committee for Scientific Survey of Air Defence constituted in 1935 under the chairmanship of Sir H. Tizard, shows the type of inquiries which arose before the war. The meteorological questions concerned the frequency with which searchlights and guns would be hampered by cloud in engaging enemy bombers and the degree of inaccuracy in forecasts which would be induced by the blacking out of meteorological information from Germany

[1] M.O.O. 1967 and M.O.O. 1921. [2] A.M. File 211235/32.

[3] The general plan of the handbooks was: Vol. I, General information; Vol. II, Local Information; Vol. III, Aids to Forecasting.

and certain other countries. The Director of the Meteorological Office gave evidence and the Forecast Division produced various memoranda on these subjects for this committee.[1]

In the summer of 1939, when the threat to Poland appeared imminent, the Aviation Services Division compiled an Aviation Meteorological Report on that country, a limited number of copies of which were issued in advance to the Senior Meteorological Officers at the Bomber Group H.Q.

Naval Handbooks on Weather

As already mentioned, it was arranged before the war, at the request of the Admiralty, for the Climatological Division of the Meteorological Office to produce a series of climatological handbooks for the oceans and sea areas. The three Volumes of the Handbook of Weather in the Mediterranean were completed between 1935 and 1939, and a handbook on Weather in the China Seas and in the Western Part of the North Pacific Ocean, also in three parts, was published in 1937/8. Early in 1938, work was started on a Handbook of the East Indies Station and later in the year, at Admiralty request, a start was made also with Vols. II and III of the Handbook for the Home Station,[2] work on the two handbooks running concurrently. The importance of these handbooks in providing from the very beginning of the war a collected body of printed uniform climatic data for the Mediterranean Sea and parts of the Home Waters need not be emphasised. They later amply justified the labour and care with which they had been prepared.

On the outbreak of war, work on the East Indies Station and on Vol. III for the Home Station was suspended in order to concentrate on the immediate production of Vol. II for the Home Station, particularly on those parts dealing with areas likely to become theatres of war. Later, as the military situation changed, the production of Vol. II of the East Indies was pressed forward. Throughout the war, the programme was constantly adjusted to meet the current needs of the Admiralty.[3] A section on Madagascar was also prepared, but the typescript was sent to South Africa when it was learned that a handbook on that area was being prepared there. Some work was also done on a volume for the East Coast of South America but publication was postponed. Handbooks of similar scope and very similar design were prepared locally during the war, that for South Africa by collaboration between the Meteorological Service of the Royal Navy and the South African Air Force, and that for Australia by the Royal Australian Air Force.

In 1938, the Admiralty appointed two retired naval officers to write the handbooks in collaboration with two technical officers of the Meteorological Office. The Admiralty and Air Ministry met the cost jointly. This arrangement continued with slight modification until April 1940 when one of the naval officers was withdrawn: the other was also withdrawn for other work in August 1940. As no replacements for the naval officers were immediately forthcoming, the offer of Mr. W. G. Kendrew, University Reader in Climatology at Oxford, to help in the work of the climatology division, was accepted. He spent several weeks in the summer of 1940 preparing Vol. I of the Home

[1] A.M. Files 240600/33 and 594584/36.

[2] A.M. Files S.35576 and S.41509.

[3] A list of the handbooks published is given at Appendix 26.

Stations and, later, a further Christmas vacation on Vol. II. The Admiralty appointed an Instructor Commander in September 1940 to meet the need for a volume on Forecasting in the East Indies Station. His period of service continued until March 1942, after which he gave part-time assistance for some months while the volume was passing through the Press. After the end of 1942, the handbooks were written without further appointments by the Admiralty but valuable help was obtained from Dr. P. R. Crowe, Lecturer in Geography at Glasgow University, who, after working for a year on the staff of the section, returned to the University but continued to help in the work partly in Glasgow and partly, during the vacations, at Stonehouse.

During most of the war, a close liaison was maintained with the Naval Meteorological Branch by a fortnightly visit of the Senior Officer of the Section to the N.M.B. and by occasional visits of the N.M.B. liaison officer to Stonehouse.

Organisation for Dealing with Inquiries and Investigations

The evacuation, on the outbreak of war, of the Climatological Division and the Meteorological Office Library to Stonehouse, caused communication difficulties. The Headquarters Branches remaining at Victory House were virtually cut off from the supply of climatic data for immediate inquiries, except in so far as it could be obtained from standard books of reference and from the climatic data available at Headquarters. Any inquiries for climatic appreciations for military purposes were referred to the R.A.F. Services Branch or the Army Services Branch, as the case might be, for answers to be prepared. In order to make data to answer such inquiries readily available, the R.A.F. Services Branch compiled aviation meteorological reports on Northern Germany (issued in 1939) and Southern Scandinavia and Denmark (issued early in 1940) in addition to various minor notes which were manifold and distributed to the meteorological officers at Command and Group H.Q. in order that they should be in a position to advise the Air Staff. The Army Services Branch similarly tried to anticipate climatic inquiries for the region around Rumania and the Balkans generally. In addition, the officer in charge of the Meteorological Section in France, who had detailed an officer for answering the climatic inquiries, collected climatic data for the front line area in France and for the North-Eastern part of that country.

After the fall of France, inquiries from the highest level became insistent. These were mostly for the average frequency with which meteorological conditions would favour various types of invasion by the enemy. In June 1940, it was decided that a separate section in the Meteorological Office was needed to deal with technical inquiries at Headquarters. This section would be 'concerned primarily with investigations on behalf of the Royal Air Force and the Army' and was to 'make contact with Divisions at Stonehouse and Dunstable as necessary. A year later, the responsibility of this Section for Investigations was further defined as dealing with demands (or anticipated future demands) for information which required quick personal consultations with staff in London; were of a semi-synoptic character; related to proposed sites for aerodromes; necessitated 'Aviation Meteorological Reports.' The basic data required in the last two types of demand were to be obtained from Stonehouse, and demands for climatological information other than those

mentioned above were to be referred to the climatological branches at Stonehouse.[1] In the early days, although the Army or Air Staffs occasionally asked for data to enable plans to be made, most inquiries concerned tactics rather than strategy and were received by the Investigations Branch through the Army Services Branch or the Royal Air Force Branch. Many technical inquiries of a comparatively minor nature were received from other sources, and the Section answered 104 technical inquiries in its first six months and 255 in the six months from July to December 1944. One of the first tasks of the Section (later Branch) was to produce an Aviation Meteorological Report on Northern France and the Channel; this was circulated in typescript in time for the Battle of Britain.[2] The work of the Investigation Branch expanded rapidly for the remainder of the war.

The most important and constant source of inquiries was the Joint Planning Staff which served the Chiefs of Staff Committee. The Joint Planning Staff was headed by the Director of Plans for the Admiralty, the War Office and the Air Ministry and had three operating sections: the Strategic Planning Section; the Future Operational Planning Section; the Executive Planning Section. Each section was composed of representatives of the three Services and they obtained their information through an Intelligence Section (Operations), I.S.(O), whose main duty was to act as liaison between the planners and the various sources of information, provided, of course, that the information was not contained in the Inter-Service Intelligence Summaries or other reference book. The I.S.(O) obtained data on meteorological questions from the Meteorological Investigations Branch. Usually the requests were brought by an officer of I.S.(O) and a reply was sent in writing but on a number of occasions, particularly in the later stages of the war and when the questions were not straightforward, direct contact was made between the Investigations Branch and the Army and Air Representatives of the Planning Sections. On the Naval side, the Director of the Naval Meteorological Service was called on similarly by I.S.(O) to furnish meteorological information.

In addition to the Planning Sections of the Joint Planning Staff, various Directorates of the Air Ministry and War Office required data which was given by the Investigations Branch. Among those to whom data were most often supplied were the Directorates of Intelligence, War Office and Air Ministry; Directorate of Plans, Air Ministry; and Directorate of Operations, Air Ministry. In particular, constant liaison was maintained with A.I.2(b) who were responsible for information about airfields, and many questions were answered from that quarter.

When the Joint Staff had built up, and the Chiefs of Staff Committee accepted, a plan, a Force Commander was chosen and the operation was mounted. The Force Commander and his staff needed meteorological advice on the plan and its details. This was supplied by the Chief Meteorological Officer appointed to the Force, who obtained help from the various branches of the Meteorological Office or, in some cases, was able to supply it from his own resources. This latter course became more and more necessary after the operation had been launched, and when the Chief Meteorological Officer himself had moved overseas. In the preparation for the North Africa landing in the late autumn of 1942, the

[1] M.O.O. 2020 and M.O.O. 2031.

[2] A list of the Aviation Meteorological Reports is given in Appendix 27.

Senior Meteorological Officer supplied the climatological information required, with the aid of the Climatological Branch of the Meteorological Office. Most of the meteorological data for plans and operations made in the Middle East were supplied by the Chief Meteorological Officer from Cairo. In India, the Chief Meteorological Officer supplied most of the information required from data which he collected from the Indian Meteorological Department, but a certain amount of planning was done in England, for which information was needed from the London office. The Chief Meteorological Officer for the Normandy landing was appointed in January 1944. Data which Combined Operations had previously requested regarding winds, visibility, cloud and sea for various reaches of the French Coast, were used in the initial planning. The Chief of Staff to the Supreme Allied Commander made many requests for information and, during the whole of the preparations, many meteorological questions had to be answered.

Liaison with Naval Meteorological Service

Close liaison was always maintained with the Naval Meteorological Service. The meteorological sections of the Inter-Service Intelligence Summaries were prepared in collaboration with the Naval Meteorological Service; the Meteorological Office wrote the draft and the Naval Meteorological Service contributed sections specially germane to the Naval operations. The whole report was then reviewed by each contributor. In addition, questions were constantly arising which needed the closest collaboration and on a number of occasions it was found convenient for Naval officers to work in the offices of the Investigation Branch.

Towards the end of the war, Naval power was exercised more and more in the Pacific and as naval meteorologists preparing for that theatre needed guidance, very close co-operation developed in certain researches on Pacific weather.

Meteorological Sections of Inter-Service Intelligence Summaries

In the spring of 1941, demands for information began to be received from the Topographical Section of the Joint Intelligence Committee at Oxford. This section had been set up by the Chief of Staff and was controlled by the Joint Intelligence Committee, on whose behalf it was administered by the Director of Naval Intelligence (D.N.I.).[1] At that time, D.N.I. had under him two parties of writers preparing climatic descriptions:—

(*a*) The Topographical Section of the Joint Intelligence Committee who were making reports on the effect of climate on operations, which were printed in Inter-Service Intelligence Summaries (ISIS).

(*b*) The Geographical Sections (at Oxford and Cambridge) who were preparing Geographical Handbooks for various countries; the handbooks were wholly a Naval commitment and were written for much more general purposes than the Inter-Service Intelligence Summaries, being intended for a wide dissemination throughout the Services.

It was found that the work of the Director of the Naval Meteorological Service and that of the Director of the Meteorological Office overlapped considerably. In order to ensure co-ordination between the Naval Meteorological

[1] A.M. File S.59525.

Service and the Meteorological Office on these matters, it was agreed in June 1941 that the staff of the Geographical Sections of D.N.I. should obtain the data they required for the Geographical Handbooks from the Climatological Branch of the Meteorological Office (through D.N.M.S. if necessary). It was also agreed that the text of the meteorological sections of the Inter-Service Intelligence Summaries should be prepared by the Meteorological Office and the Naval Meteorological Service in collaboration, and not by the staff of the Topographical Section as hitherto. It was decided to draw up a detailed scheme for the preparation of the meteorological sections in accordance with the requirements of the Joint Plans Committee. These two decisions formed the basis on which climatic information was subsequently supplied.

In December 1941, a meeting attended by the Directors of the Naval Meteorological Service and the Meteorological Office, and the Heads of the Climatological and Investigations Branches, decided that the Intelligence Summaries should consist of a précis of the main climatological features of the area under consideration and meteorological features liable to affect operations, divided into appropriate sub-headings. It also decided that the Climatological Branch should apply the fundamental memoranda for the greater part of these sections, which should then be passed to the Naval Meteorological Service and to the Investigation Section who would collaborate in putting them in an agreed form for the Intelligence Summaries.[1] It was further agreed that the Investigation Section should be responsible for preparing operational memoranda which would form the reference books of the meteorologists who accompanied the Expeditionary Force, and who had to act as meteorological advisers and forecasters to the officer directing operations. The Aviation Meteorological Reports were subsequently prepared and issued with this object in view, the fundamental data being obtained from the Climatological Branch.

After considerable discussion between representatives of D.M.O. and D.N.M.S. and the Planning Staff, a form of layout for the Intelligence Summaries was agreed and certain guiding principles were laid down for the drawing up of appreciations. These were completed in November 1942[2] and, with a few amplifications, were in force for the rest of the war.

When the German Armies finally surrendered on 8 May 1945, intense work was being done to produce a report for the Inter-Service Topographical Department on Southern Norway in case the Germans should use that area as a final stronghold.

Reports on Airfields for the Summaries : After the hold-up in operations in Tunisia in the winter of 1942–43 owing to heavy rains affecting the ground, the Investigation Branch asked the Planning Staff what were the critical amounts of rain which affected ' going.' This inquiry eventually contributed to the decision, in about November 1943, to form a Geological and Soil Section at the Inter-Service Topographical Department. At a meeting on 24 November 1943, attended by the Head of the Meteorological Investigations Branch, it was decided to prepare soil maps to help in the selection of airfield sites in enemy-held territory and to accompany the maps by meteorological notes prepared in the Meteorological Office.[3] These meteorological notes were eventually incorporated in the airfield section of the Inter-Service Intelligence Summaries.

[1] A.M. File S.78802. [2] A.M. File S.59525. [3] A.M. File S.96519.

The following reports were drawn up for this purpose :—

Malaya	January 1944
Middle Danube Area	February 1944
Northern Sumatra	March 1944
Formosa	April 1944
Bulgaria	May 1944
Southern Indo-China	August 1944
Northern Borneo	August 1944
Kra Isthmus	August 1944
Hainan	October 1944
Central Sumatra	October 1944
Hong Kong and Canton Area	February 1945
South-East China	February 1945
Java	March 1945
Siam	April 1945.

Methods of Preparing Summaries : The type of information which the planner needs is not easily produced from mere statistical tables. He needs, first, a mental picture of the climate of the country he is interested in and the details readily available of the precise location, perhaps only a few yards of beach, for which he is planning. It is very unlikely that for those few yards, or even for a comparable position, there are meteorological statistics available of unimpeachable accuracy, but the planner cannot be expected to assess the applicability and accuracy of data from a neighbouring site. An attempt to meet this was made in the Intelligence Summaries, but the type of question which was repeatedly asked was ' what is the probability that such and such an operation can be undertaken in such and such a month ? ' Not infrequently, the meteorologist then had to ask for details of the precise spots of the operation and the precise ranges of conditions and combinations of conditions which would prevent the operation, before he could attempt an assessment.

Various expedients were used to frame answers in the form which the planner needed. The final answer was often based on the meteorologist's judgment after weighing up any relevant statistics. Quite a number of questions were answered by posing a problem to two or three meteorologists with long experience of forecasting weather over North-West Europe and asking them to estimate the frequency of occurrence of such and such conditions. The agreement between their independent opinions gave some idea of the accuracy of the frequency which they gave. To give the picture needed by the planner, the meteorologist had always to have in the background of his mind the synoptic situations which might occur, and it was found that an essential preparation for answering questions regarding any particular area was to glance over several years of synoptic charts, full weight being given to the topographic features. Full use was also made of any and all the more usual climatological data which could be provided ; there was always available the bulk of climatological data which the library at Stonehouse and the Climatological Branch could furnish. In this connection, the liaison between Stonehouse and London had to be close ; it was furthered by the fortnightly visits which a member of the Climatological Branch paid to the Air Ministry in London and to the Naval Meteorological Branch.

The Deputy Director devised special statistics which combined criteria of cloud height, visibility and wind into a single unit. These 'Index figures' were calculated for a number of continental stations and proved very useful in quick assessments of comparative conditions. In the British Isles, more elaborate 'Fitness Figures' were used statistically in a similar way.

The importance of the possession of a collection of the back numbers of Daily Weather Reports of all nations will be realised. The excellence of the German Daily Weather Reports was much appreciated, but it was found at the beginning of the war that only one set of such reports existed in the country. On the other hand, inadequacy of the French and Italian Daily Weather Reports was a handicap. It was found that synoptic data for Malaya and the East Indies were totally lacking as the daily data had never been published and the whole series of manuscript maps which had been drawn in Malaya had fallen into Japanese hands when Singapore surrendered. It is impossible to assess how much this loss hampered the giving of sound advice on that area.

The Use of Meteorology in Planning

It is impossible to record all the requests for advice which were made, but the following paragraphs show some of the problems which had to be faced.

Attacks on Germany with Free Balloons : A scheme was considered in September 1940 for allowing barrage balloons to drift over Germany with trailing cables. As the merit of the scheme depended on the comparative frequency with which it could be used by, and against, the United Kingdom, the project was referred to the Meteorological Office. The resulting examination showed that owing to the extended coast-line occupied by the enemy this method of attack could be used more often against than by the United Kingdom.

Attacks with incendiary balloons were considered in April 1941, but again the investigation showed that it could be of more danger to the United Kingdom than to the enemy. The project was revived in November 1941 with a suggestion for using balloons which floated at a constant height for a given time. The use of greater heights for the travel of the balloons enables the frequency of their use to be raised appreciably, and turned the balance in favour of the United Kingdom, which fact was duly shown by the statistics provided to the planners. A difficulty arose with these balloons on trial in that on a number of occasions when the test balloon descended at night, its descent was arrested, but later it shot up high into the air. This fact was reported to the Meteorological Office who explained that the descending balloon was super-cooled by its loss by radiation at night. This super-cooling was lost when it entered a layer of strato-cumulus cloud, and so the balloon remained at constant level. In the morning, the sun's radiation super-heated the balloon and it consequently shot up into the air.

Inquiry into the German Bomber Operations of the Winters of 1940, 1941 and 1942 : In January 1943, a request was made for a comparison of the effects of weather on the effort made by the German Bomber Force during October, November and December of 1940, 1941 and 1942. The answer to this was needed to test the idea that we were making less effort than the Germans had made. By using indices of weather fitness for various areas of the Continent covering the German bases it was possible to get a comparison with similar

indices of weather fitness for representative British bases. As a result of these statistics, it was decided that the greater German activity was due entirely to their having a more extensive choice of bases and that there appeared to have been a very substantial loss of enemy aircraft due to their neglect of weather in October 1940 and to less extent in November and December 1940.

The Dust Storms of Tripoli and Tunisia : As soon as it was realised in November 1942 that the British Armies would be fighting in North Africa during the spring of 1943, it was considered that sand or dust storms occurring during a big operation might be a serious tactical danger. A member of the Investigations Branch was detailed to find out how the depressions were formed which affected Tripoli and Tunisia and gave rise to the Ghibli winds in the early months of the year. The result of his work during November and December 1942 was a paper on the formation of Lee depressions to south-east of the Atlas mountains and the method by which the formation could be forecast. This paper showed how these depressions were often the cause of Ghibli winds. The paper was manifolded and sent to the Senior Meteorological Officers in North Africa in time to reach them before the middle of February, which was the beginning of the season of Ghibli winds.

Conditions in the Valley of the Po : In 1943, when the British and American Armies were intending to invade Italy, information was accumulated regarding Northern Italy, and an intensive study was made of the synoptic conditions and their effects on the weather. As a result of this, much new light was thrown on the fundamental mechanism of the local winds at Genoa and elsewhere on the coasts and in the Po Valley.

The Planning Staff asked in October 1943 for the frequency with which airfields in North Italy could be used by heavy bombers against certain targets in Germany and how often they would be hampered by ice when crossing the Alps. The reply showed that less bombing effort could be made from North Italy in winter than from England ; a greater effort could be made from such places as Foggia, which was then in the region of operations by our forces, than from localities farther north in Italy, the capture of which would have entailed very large scale operations. The reply was viewed with some scepticism until a prisoner of war confirmed it.

The Landing in France : As early as 1941, a meteorological section had been prepared for an Intelligence Summary on North-West France, and various statistical data had been prepared for that area in special forms ; for example, the Chief of Combined Operations had asked for a tabulation of the winds in various sectors of the French, Belgian and Dutch coasts for each day of ten years, together with visibility, in order to inter-relate them with other data. Calculations had been made from these data of the chance of quiet conditions for various spells at different times of year. In July 1943, the first detailed inquiries for the landing were made. These involved the estimation of frequencies of cloud amount and height by night over both Normandy and England, as well as visibility. The lack of records of observations in France was very severely felt, particularly in regard to night-time observations.

A great deal of discussion arose as to the probability of a long enough spell of quiet conditions to enable the build-up to be effected. Four separate examinations were made of the day by day weather of ten or twenty years, and subsequent computations of the chance of a serious break in quiet conditions.

(It so happened that the period from 6 June to 5 July 1944 was persistently unsettled with a period of strong north-east winds. When the records for the last 50 years were subsequently examined, it was found that only in 1907 had June been a windier month than in 1944; 1928 and 1938 were only slightly less windy.)

A meteorological estimate was made of the most suitable airfields in England for use by the glider force, and a list was given to the Royal Engineers of the probable meteorological characteristics of every piece of land in Normandy which could be converted into a landing strip. This was done for the whole invasion area as far south as the high ground. This list was subsequently extended as far east as Paris.

The Bombing of a Lake near Modane: In September 1943, the Senior Meteorological Officer, No. 5 Group, asked the date of freezing and the thickness of ice in a lake near Modane, as well as the probable amount of water in the lake at different seasons. The information was needed in order to decide how the lake dam could be attacked so as to destroy the French-Italian railway link. This proved a particularly difficult inquiry to answer as no data were available for the lake itself and it was known that the dates of freezing varied not only with height but also with the exposure and dimension of the lake. The estimates given were consequently of a very uncertain quality.

Trafficability: After the meeting on 24 November 1943, which had already been mentioned, it was felt that there was still room for the use of meteorological advice to the Army in relation to the movement of heavy vehicles over the ground.[1]

After discussions with the Road Research Laboratory of the Department of Scientific and Industrial Research, the Deputy Director, Meteorological Office, called a meeting on 3 February 1944 to discuss the problem of 'trafficability' as affected by meteorological, geological and soil physics factors. In addition to the Chairman, there were present the Chief and Deputy Chief Meteorological Officers, SHAEF, and representatives of the U.S.A.A.F., Rothamsted Experimental Station, H.M. Geological Survey, Inter-Service Topographical Department, Road Research Laboratory, School of Tank Technology and the Meteorological Office. The discussion showed the demand for information from the planners to be insistent and that there were no data in a suitable form to satisfy that demand. Various methods of approach were suggested. These were subsequently pursued and led to an advance on the meteorological side, in that a relation was found between the rainfall and evaporation on the one hand and the dates between which the soil was at 'field capacity.' The link between the state of the soil and the 'going' of tanks and heavy vehicles was still missing. The Army Operations Group and the School of Tank Technology made an independent attempt to gather information on this point. This was pursued at a trial site near Ayr, and a member of the Investigations Branch assisted in these trials.

In order that the meteorologists who were attached to the invading forces should be in the best position to give advice to the Army authorities, all meteorological officers proceeding overseas were called to a meeting at the end of May 1944 and were given lectures by officers of the Investigations Branch on the soil of North-West Europe, the problem of 'trafficability' and the relation of 'field capacity,' rainfall and evaporation.

[1] A.M. File S.98098.

The Deputy Director suggested in June 1944 that a qualified meteorologist-geologist should be attached to the Invasion Forces in order to give advice on the problem of soil. The Scientific Adviser to the War Office at once received this proposal favourably but it was not until 31 December 1944 that the officer selected proceeded to Twenty-First Army Group H.Q. His duties then were to advise on climatology generally as well as to give any help he could in the matter of soil to the geologist attached to Twenty-First Army Group.

In addition to the work on trafficability which was being done for the Army in the Low Countries and Germany, an organisation had been evolved for giving advice in Italy, a squadron leader of the Meteorological Office Staff being delegated as the adviser. In that case, rain gauges and evaporation tanks were installed at certain places in order to get exact daily values. Information on these matters was also sent to the Chief Meteorological Officer South East Asia Command.

Because further information was needed on the rate of evaporation from various types of vegetation and soil cover, some experiments were made at Rothamsted to determine the rates of evaporation from various types of soil. The experiments were still being made when the war ended.[1]

The Flying Bombs: Information was needed in December 1943 on the frequency with which various types of bombers could make pin point attacks on certain special targets in North France, the purpose being to assess the bomber effort which might have to be diverted from Germany in order to check the building of flying bomb landing sites. By using cloud amount and height frequencies, it was estimated that the frequency of certain conditions in the middle of the day would be as follows, the conditions being designed to allow attacks to be made by (*a*) Fighter/Bombers and Mosquitoes, (*b*) Medium Bombers and (*c*) Heavy Bombers :—

	No cloud below 1,000 feet.	*Less than $\frac{7}{10}$ below 10,000 feet and visibility 6 or more.*	*Less than $\frac{4}{10}$ below 12,000 feet.*
	(*a*)	(*b*)	(*c*)
January	18 to 20	12	5
February	18 to 20	13	4 to 5
March	25	14	6 to 7

It was emphasised that these conditions applied to the average year and that individual years differed widely.

The number of days when conditions were good enough for operations to be attempted were :—

	Fighter/Bombers and Mosquitoes	*Medium Bombers*	*Heavy Bombers*
January	31	11	2
February	31	15	2
March	28	15	1

In these months, the low level and medium bombers operated every day on which it was possible, but the heavy bombers did not.

[1] A.M. File S.103984.

The use of Fighter Aircraft across Sumatra : A plan was at one time considered for an operation against the west coast of Sumatra to establish airfields from which fighter support might have been provided for a larger scale operation against the north-eastern coast of Sumatra. The problem posed was 'how often will aircraft be able to fly across the Sumatran mountains in formation without encountering icing and destructive gusts.'

No daily observations were available and the climatological observations were almost entirely useless to answer this question except for a few statistics of thunder and for the average monthly rainfall at a considerable number of stations in Sumatra. The question could not, therefore, be answered with great confidence. An estimate was given, based on these few data, that cloud would often be heavy during the afternoons and much of the night and often extend to very great heights. Owing mainly to this adverse advice, the project was abandoned. The estimate was subsequently corroborated by a Dutch pilot who had had experience of flying in that region.

Meteorological Conditions in the Far East Theatre : It was deduced in July 1943, that the final conquest of Japan would involve the operation of heavy bombers from bases in or near North-East China. As our knowledge of that area was quite rudimentary, it was decided that as soon as an opportunity arose, a competent forecaster should try to analyse daily observations over the whole of Eastern Asia, and write down the results in such a way as to provide an introduction for forecasters to the climate and weather of the Eastern Theatre.[1]

In July 1944, when the pressure of work for the landings in France had subsided, a member of the Investigations Branch was able to devote all his time to this work. At about the same time, the Naval Meteorological Branch of the Admiralty also began to concentrate on the climate of this area and after a meeting had been held to delegate specific lines of approach, work proceeded rapidly, resulting in a contribution from the Meteorological Office of the following Aviation Meteorological Reports :—

M.O.M. 365/24 China, Japan and Adjacent Areas.
M.O.M. 365/27 Main Islands of Japan.
M.O.M. 365/28 Ryukyu Islands.
M.O.M. 365/29 South China.
M.O.M. 365/30 North China, Manchuria and Korea.

In order that the Investigation Branch might be fully briefed to answer questions on the southern part of the area, a member of the pre-war Malayan Meteorological Service worked in the Investigation Branch from July to October 1944.

Fairly extensive reports were compiled for the south-western part of the Far East Theatre, and a short memorandum (M.O.M. 369) 'Notes on the Weather of the Far East Theatre' was written specially for the planner and the pilot new to that region.

When Sir Hugh P. Lloyd asked in January 1945 for information on the meteorological conditions for bombing operations against Japan, the Meteorological Office was able to give the results of considerable paper experience, fortified with first-hand information of the weather experienced by several competent observers who had been in the Far East.

[1] A.M. File S.100208.

In June and July 1945, when Tiger Force was being assembled in Lincolnshire, the meteorological officer who was to act as chief forecaster visited the Investigation Branch and examined the work which had been done of the weather of the Far East. The member of the Investigation Branch who had been working full time on the subject accompanied him on his subsequent move to Grantham and spent about six weeks, until the fall of Japan, lecturing to the forecasters who had been chosen to go to the Far East, on the climate and weather of the region.

During the work on the climate of the Far East, it was realised that the newly arrived forecaster might not be able to assess the significance of pressure tendencies, because the diurnal variation of pressure in those parts is so different from that in Europe. The Climatological Branch, therefore, examined all the normal values of the diurnal variation of pressure which could be obtained for Eastern and Southern Asia, and produced maps on which were plotted the normal values of tendency. These maps were sent to the Meteorological Officers concerned, both those working with the Royal Air Force and those with the Navy.

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The type of statistics which are normally included under the heading of climatology are not enough for the planning operations. The planner needs special statistics and impressions, many of which can only be obtained from daily weather maps and observations made daily at frequent intervals. It is, therefore, essential that synoptic charts covering several years should be preserved for all regions of the globe.

Synoptic weather data in coded form are easily handled material, which, if punched on Hollerith cards, for enough places, would provide a ready method of getting statistical frequencies and correlations in order to supplement the usual climatic summaries and the impressions derived from the synoptic charts.

The meteorological advice given to the planner is likely to be far more apposite if the meteorologist is aware of the plan, for he may then see meteorological points which the planner cannot hope to embrace in any series of questions which he may ask. For example, the chance of bombing a certain target visually from a high altitude might be confined to occasions when the wind was from a certain direction only, but the meteorological situation which produced such a wind might necessarily be associated with certain conditions on the route to the target, such as winds from specific directions, which would impose limits on the ground speed and consequently on the bomb-loads. This could well be vital to the plan but unless the meteorologist was fully briefed, the planner could only stumble on the true facts by accident. In fact, the meteorologist's advice to the planners was considered to be most to the point on those occasions when the meteorologist worked side by side with a member of the planning staff in drawing up the report on the prospects of the operation. The liaison between the planners and their meteorological advisers must, therefore, be of the very closest. There would probably be great advantages if they occupied the same building as, of course, was done in the preparations for the North African landing and in the preliminaries to D Day.

The preparation of meteorological data may be a lengthy process, particularly, if it concerns a little known region. It is essential, therefore, that the planners should warn the meteorologist of the areas in which they are likely to be

interested a long time ahead, but the meteorologist must also deduce the regions which are going to come into the picture. For example, the data which were required for the planning of Tiger Force could not have been assembled if the Meteorological Office had waited to study the area in detail until they were told that the R.A.F. would be operating to the south-west of Japan. About a year of continuous work was needed to be prepared to give advice on that area.

Miscellaneous Investigation Work

During the first years of the war, there were very few inquiries for information for civil flying, but in the autumn of 1943 the requests from the Operational Planning Branch of the Directorate of Civil Aviation and from the President of the Airfields Board, who was then assisting in the planning of future civil operations, became numerous, and continued to increase during the remainder of the war. The inquiries were aimed at preparing for the development of air routes after the war. As a result of the inquiries, a plan was made for the orientation of airfield runways so as to give a minimum time during which there is a wind component exceeding a given speed across all the runways.

As the following paragraphs show, a large amount of information covering a wide range was supplied to assist the war effort, and later the reconstruction programme, in addition to the information supplied for problems directly connected with military planning.

Reports were prepared on the dates of freezing and thawing, break-up of ice and duration of snow cover in various theatres of war. These involved much research into the available data and into their statistical treatment. A method was devised for the rapid calculation of the dates of freezing and thawing from monthly mean temperatures.

Much information was supplied regarding the temperature of exposed objects in various parts of the world, mostly in connection with the design of equipment. These included the highest temperatures likely to be reached inside tanks and tents, the effect of heat on army rations, of heat and humidity on tele-communications equipment, problems of ventilation, etc., and of rapid changes of temperature on the focusing of aircraft cameras. Information on probable maximum temperatures in the wings and fuselages of wooden aircraft was supplied to the Forest Products Research Laboratory, and estimates of the temperatures likely to be attained by ammunition in the wings of aircraft to the Ministry of Supply.

Seasonal charts of thunderstorm frequency over the globe were drawn for the Inter-Services Ionosphere Bureau, and detailed investigations were made into the frequency, intensity and duration of falls of rain in different parts of the world in connection with the possibilities of short-wave wireless communication.

The work done for reconstruction included preparing large-scale maps of rainfall distribution over Scotland for the North of Scotland Hydro-Electric Board, and associated work on wind as source of electric power for the British Electrical and Applied Industries.

General climatic information was supplied in connection with increasing food production, controlling pests, siting hospitals and replanning bombed areas. Data on the average amount and variability of rainfall were needed for

estimating water supplies for camp sites and factories, and on the frequency of heavy showers for drainage of camps and airfields. Information was supplied on the maximum wind velocities to which buildings, hangars, etc., would be subjected. Many of the problems required extensive research and, in some cases, the development of special statistical methods.

The Meteorological Office Library

Throughout the war, the Library was fully occupied in supplying literature and information on all aspects of meteorology to the Service Ministry, Combined Operations H.Q. and many Government Departments such as the Ministry of Aircraft Production (T.R.E. Malvern, B.D.E. Cardington, etc.), Ministry of Supply (A.D.R.D.E. and Chemical Defence Research, Porton), Ministry of Economic Warfare, Department of Scientific and Industrial Research (N.P.L.), etc. The annual total of loans increased tenfold, from 3,515 in 1939–40 to well above 37,000 in each of the last three years of the war. In addition, members of the Department mentioned often visited the library to consult literature and discuss their problems.

In preparing memoranda for planning, and for the general prosecution of the war, a great demand arose for climatic bibliographies, of which 45 were compiled covering various regions of the world. These included a bibliography of Synoptic Climatology of the Far East Theatre which was prepared in 1944–45.

Watch was kept for information on meteorological papers published in enemy or enemy-occupied countries, and efforts were made to obtain some of the most important.

The Marine Branch

At the outbreak of war, the work of the Marine Branch was centred on the organisation, recruitment and maintenance of a Voluntary Observing Fleet, consisting of British Merchant Navy Vessels. In 1939, there were 360 British Regular Observing Ships, equipped with tested meteorological instruments loaned to the vessels by the Meteorological Office, making observations for broadcasting to other ships and Meteorological Services for forecast purposes. There were also 600 British Supplementary Ships performing these duties in an abridged code, when in areas where there were insufficient regular ships. The regular observing ships in the eastern North Atlantic normally contributed about 12,000 weather messages a year to the Central Forecasting Office. With the imminence of war, and in compliance with Admiralty Orders regarding W/T silence and the non-disclosure of ships' positions, all wireless weather messages from British ships ceased on 27 August 1939. However, Port Meteorological Officers and Merchant Navy Agents were instructed to continue to visit and recruit ships to the Voluntary Observing Fleet and to replenish equipment in order to maintain the Fleet and keep in contact, so that the Service could be restarted as soon as possible after the war. Despite the heavy losses in British shipping, and enemy raids at the ports, the Fleet, so far as could be estimated, stood at 272 Regular and 208 Supplementary ships at the end of the war in Europe in May 1945.

Under the Admiralty order regarding the non-disclosure of ships' positions mentioned above, the recording of meteorological observations by British observing ships also ceased in August 1939. The only marine meteorological

data received in the Branch during the war were those contained in Meteorological log books kept on board H.M. ships and forwarded to the Meteorological Office by the Naval Meteorological Service.

The war-time work of the Marine Branch was concentrated mainly on preparing climatological, sea current and ice atlases, many of which were urgently required by the Services, especially the Admiralty, for operational purposes.

Close liaison was maintained between the Naval Meteorological Service and the Tidal Branch of the Hydrographic Department of the Admiralty. Many inquiries, including the following, were dealt with from these Branches and from Home, Colonial and Allied services :—

(*a*) Copies of ships' synoptic observations at noon G.M.T. from April 1933 to August 1934 for all oceans in the belt 30° N. to 50° S. were supplied to the U.S. Naval authorities.

(*b*) A meteorological report was prepared for the investigation of the effects of exposure on shipwrecked seamen in open boats and rafts for the Research Unit, National Hospital, London.

(*c*) Mean sea surface temperatures in the Severn Estuary, covering a period of 16 years, were supplied to the Ministry of Home Security.

(*d*) Data from ships' meteorological records December 1933 to January 1935, for the area south of latitude 35° S. and from longitude 100° E. eastward to 40° W., were extracted for the London Office of the New Zealand Government.

(*e*) Data on sea temperatures and currents in connection with up-welling were supplied to the Technical Research Department of the Ministry of Aircraft Production.

(*f*) Many legal inquiries were dealt with in connection with arbitration cases arising out of shipping casualties.

Part V

SECURITY, ORGANISATION AND SUPPLY

CHAPTER 32

SECURITY

Introduction of Security Measures

The security measures involved in the meteorological war organisation such as the suppression of in-clear broadcasts and the cessation of published data, were designed to handicap the enemy as much as possible but, at the same time, maintaining the supply of meteorological data to authorised allied recipients. Inevitably, however, these measures handicapped to some extent the countries in which they were applied ; wireless messages were delayed by encyphering and decyphering, cypher staff were required and weather information was withheld from sections of the community to whom it would be useful, if not essential. In particular, the transmission of weather information to aircraft in flight was necessarily more complicated. Throughout the war, the decisions taken to introduce or relax meteorological war organisation in various areas were in essence assessments of whether the results would be a greater help or handicap to friend or foe, questions on which the Allies and the individual Services of the Allies often disagreed.

The Defence Preparedness Committee took the first step towards introducing the meteorological war organisation on 26 August 1939 when they empowered the Secretary of State for Air to impose the various measures at his discretion. Representatives of the Admiralty and Air Ministry Directorates of Intelligence, the Meteorological Office and the Naval Meteorological Service discussed the problem in more detail on the same morning and recommended that the general meteorological war organisation be put into effect 48 hours before the anticipated outbreak of war, or on the suppression by Germany of her meteorological broadcasts. As German naval strategy and Italy's intentions were then uncertain, it was decided that the areas affected should be the British Isles, North and South Atlantic, the Mediterranean area and the Red Sea, also that the Malta and Gibraltar Fleet Synoptics should be issued in cypher at once and that the French authorities should be informed of these decisions.[1] Full meteorological war organisation was finally introduced in the areas recommended on the afternoon of 1 September 1939 on instructions from the Director of Intelligence. The Dominions and Colonial Governments concerned were notified by a pre-arranged signal sent by the Dominions and Colonial Offices and the French were informed by a teleprinter message to the British Meteorological Liaison Officer in Paris.

It had become clear by 14 September 1939 that Italy had no immediate intention of entering the war and it was agreed, subject to the concurrence of the Naval C.-in-C. of the Mediterranean, to revert to peace-time procedure in Malta, Egypt and Palestine and to issue reports from those countries in clear. One or two exceptions were made to the normal full peace-time procedure,

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[1] A.M. File S.56428.

e.g., pilots were not to be shown synoptic charts containing reports from the Western Mediterranean or other security areas and no statement of the general meteorological situation which embraced any part of these areas was to be issued. It was also agreed that the Fleet Synoptics for the Eastern Mediterranean should continue in cypher. This division of the Mediterranean into a security area in the west and non-security area to the east was maintained until Italy entered the war. In October, the French suggested the issue of reports from Tunis by wireless in clear to speed up the receipt of reports in Malta and Gibraltar, but the Admiralty opposed this and the reports continued to be sent by cable. In January 1940, however, the French North Africa Air Force pressed for the transmission in clear of Tunisian reports and broadcasts of these reports in normal international code recommenced on 25 January 1940. By then, apparently, the Admiralty did not regard it as important as no protests were made to the French on their unilateral action.

Meanwhile, the Controller of the Canadian Meteorological Service and the Air Attaché in Washington had discussed with the United States authorities the delicate question of the issue of Canadian reports to the United States which had continued to issue its own reports in clear. It had at once been agreed that the close relations between the two countries made it impossible to withhold Central or Western Canadian reports as these were most important to the United States, and such a restriction would cause serious political repercussions. The United States authorities agreed to cease broadcasting these reports in clear by wireless but considered it necessary to continue to broadcast them by teleprinters which were accessible to many agencies. It was clear that an enemy agent might obtain access to them and cable them to Germany, but in view of their comparatively minor importance for operations in the Eastern Atlantic and Europe, the Air Ministry were prepared to waive their objections. The position regarding the reports from Eastern Canada was more satisfactory, as it was agreed that they should be issued in confidential code to a very limited number of recipients in the United States. As the Canadian reports were considered essential to the Atlantic Squadron of the U.S. Navy it was agreed that the Naval Station at Arlington should continue to broadcast them, but in Naval confidential code. Similar arrangements were agreed regarding the reports from Bermuda, but a request by the United States authorities that the European reports received in Canada in confidential code should be passed on to them was refused. The United States authorities on their part undertook to ensure that the reports issued by Pan-American Airways in connection with Atlantic flying would be issued in a confidential code.

On 12 November 1939, at the wish of the Admiralty, the areas covered by meteorological war organisation were extended to include the East Indies and South Atlantic Stations. The land areas affected were the Falkland Islands, British West Africa, the Union of South Africa,[1] British East Africa, Aden and British Somaliland, India, Burma, Ceylon and the islands under British control in the Indian Ocean westward of 95° E. longitude. An exception was made in the case of Iraq in view of its position at the head of the Persian Gulf and of the administrative and political difficulties involved. The Eastern

[1] Although the original recommendation of 26 August 1939 included the South Atlantic, meteorological war organisation does not appear to have been introduced either in British West Africa or in South Africa.

Mediterranean and the Red Sea remained non-security areas. The Portuguese authorities in Mozambique were persuaded to suppress the wireless transmission of reports from that area, but the French Naval authorities decided to continue to issue reports from Madagascar and Reunion in clear. This situation was discussed by British and French representatives in London in February 1940 and a procedure agreed for prior consultation between the British and French Naval authorities on any future occasion. In view of the difficulties which were being experienced in Madagascar because of the encyphering of reports from neighbouring British territories, the French representatives asked the Admiralty to review their decision regarding the Indian Ocean.[1] Lengthy consultations between the Admiralty, the C.-in-C. East Indies and the French Naval authorities ensued and the Admiralty replied on 6 June 1940 that the position had been explained to the French Admiralty and arrangements had been made for the Madagascar broadcasts to be encyphered. Within a few days, however, France fell, and, as Madagascar went over to the Vichy Government, the arrangements came to nought.

Early in 1940 the situation in the Atlantic was complicated by a decision of the United States Weather Bureau to post two cutters between Bermuda and the Azores for the purpose of making and reporting weather observations. When the first hint of this proposal was obtained, the Air Attaché in Washington was instructed to press for a secret code to be used for the reports. For some time the Air Attaché was unable to obtain more definite information, but on 14 February 1940, he reported that a sudden decision had been made to dispatch the cutters, and that the Weather Bureau were unwilling to use secret code. The Air Attaché was instructed to press the matter further in view of the value of the reports for forecasting in Western Europe and their possibly vital importance in certain circumstances of naval operations. The Controller of the Canadian Meteorological Service acted as intermediary, as was usual in meteorological negotiations with the United States at that time, and his good offices were mainly responsible for a 'Gentleman's agreement' being reached early in March that the Weather Bureau would endeavour to have a secret code used for the reports. The Weather Bureau, however, referred the matter to the State Department and by June no decision had been reached, the reports in the meantime being issued in clear. Renewed representations were made, and on 9 June 1940, the Air Attaché reported that the State Department had agreed that cyphers would be used for the cutters' reports and for all meteorological information east of 65° W. longitude. A little earlier, another important step in tightening the 'meteorological blockade' in the Atlantic had been taken, viz. the occupation of Iceland by British troops in May 1940, and the suppression of broadcasts of meteorological data in clear from that country.

In view of the war situation, preliminary arrangements were made in mid-May 1940 to reintroduce meteorological security in the Eastern Mediterranean and Middle East, and the Admiralty informed the Air Ministry on 31 May 1940 that they had agreed with the French Admiralty that meteorological security should be reintroduced in that area as soon as possible. The

[1] The nature of the difficulties experienced by the French is not clear. It may be that they had not completed the distribution of the British meteorological cyphers which had been issued to them. A.M. File S.56428.

signals reintroducing meteorological war organisation in the Eastern Mediterranean and Red Sea and extending it to Iraq and the Sudan forthwith were eventually dispatched on 10 June 1940.

The signing of the Tripartite Pact between Germany, Italy and Japan in September 1940 made it highly probable that meteorological war organisation would have to be introduced in the Far East. The preliminaries were considered but, as Japan made no move, no further action was taken. In February 1941 the situation appears to have been critical again, and the Admiralty suggested on 1 March 1941, that meteorological security should be introduced forthwith in British territories on the China, Australian and New Zealand stations. It was agreed that this should be done from 9 March 1941 for all British territory between 95° E.[1] and a line joining the following points: 70° N. 180° E., 30° N. 180° E., 30° N. 150° W., 0° 120° W., 70° S. 120° W. The Governments of Australia, New Zealand and Canada and of the various colonies concerned were notified, and the United States, Netherlands and Free French Governments were also informed. It was emphasised to the Dominions Governments that 'this is merely a precautionary measure and does not arise from any apprehension as to the immediate situation in the area concerned.'[2]

The attack on Pearl Harbour and Japan's entry into the war marked the beginning of the period of maximum meteorological 'blackout.' Meteorological security was introduced at once in the United States, in Central and Western Canada, and, in varying degrees of effectiveness, in the South American countries. As meteorological security had already been introduced in 1939 in enemy and enemy-occupied territory, and in the U.S.S.R., Switzerland and Sweden, the broadcasts of a few isolated neutrals such as Spain, Portugal and the Azores were all that remained of the complex peace-time world-wide exchange of meteorological data. The tendency from this point onwards was to relax restrictions as the war situation improved for the Allies.

Relaxation of Security Remote from Main Theatres of Operations

Africa

The relaxation of meteorological security was first considered in the Sudan, Central, West and South Africa. As early as April 1941 West Africa and South Africa had suggested that security restrictions should be removed or at least relaxed, but this had been turned down by the Admiralty. In September 1942 the matter was again raised by the Resident Minister in West Africa because of the delays and difficulties caused on the reinforcement routes. The security arrangements along the African reinforcing and delivery routes had, in fact, become increasingly unsatisfactory, mainly owing to the great increase in air traffic in the area, the advent of American personnel who were unaccustomed to meteorological security restrictions and who could see no overwhelming reason for applying them in those areas, and the lack of a simple and secure cypher for transmitting weather reports to aircraft. A contributory factor was the employment of native personnel without European supervision at many wireless stations along the routes. The result was that a good deal of weather information was being transmitted in clear, and the meteorological security regulations had come to be regarded by aircrews and others as a formality.

[1] Meteorological War Organisation was already in force west of this line.
[2] A.M. File S.56428.

A Meteorological Office note in November 1942 suggested that meteorological security might be abandoned in the Sudan and possibly in West Africa, Abyssinia and Eritrea. The main reasons put forward for this step were:—[1]

(*a*) The employment of native personnel at the wireless stations which ruled out the use of cypher and rendered the other security precautions largely ineffective.

(*b*) The transmission of weather information in clear from adjacent Free French and Belgian territories.

(*c*) The risk of the transmission of weather information both in clear and in cypher compromising the meteorological cypher in use, and thus giving the enemy access to weather information from more important areas.

(*d*) The transmission of weather information in clear would simplify delivery of aircraft on the Middle East reinforcing route.

The matter was brought to a head early in December 1942 when, as a repercussion of the North Africa landings, the meteorological services in French West Africa, until then under Vichy control, began to broadcast their meteorological data in clear. The whole problem was reviewed at a meeting with the Admiralty which was held on 20 January 1943 after obtaining the views of the Naval Commanders-in-Chief and the Air Officers Commanding in the areas concerned. The meeting brought out very clearly the difference in view point, which remained until the end of the war, between the Admiralty and Air Ministry on the question of maintaining meteorological security. The Admiralty was mainly concerned with the transmission of meteorological data to ships, for which purpose it was comparatively simple to provide a secure cypher of the type used for the exchange of data between land stations. The delay caused by the encyphering and decyphering of these messages was undesirable but not vital. The Admiralty, therefore, favoured maintaining meteorological security if this would handicap the enemy in any way. The Air Ministry on the other hand, was, in addition, concerned with the transmission of weather information, particularly landing reports, to aircraft. The provision of a simple and secure cypher for this purpose was an extremely difficult problem which remained unsolved until the end of the war. To maintain meteorological security, it was necessary to reduce to a minimum the amount of weather information transmitted to aircraft and to use a relatively complex cypher which was unpopular with aircrews and with the ground staff responsible for their safe operation. In-clear transmissions to aircraft were permitted only in cases of emergency. The rigid application of these regulations was considered to have an adverse psychological effect on the less experienced aircrews, and during the last few years of the war the R.A.F. and U.S. Transport Commands pressed strongly for the relaxation of meteorological security in any area where it appeared in the least justifiable. The Air Ministry had, therefore, to consider whether the advantages of relaxation for our own air operations outweighed the advantages which the enemy would obtain from his knowledge of the weather in the area. The Meteorological Office role in these discussions was to advise on the latter point and to try to assess the advantages which the enemy forecasters would gain. An increasing doubt regarding the security of the main

[1] A.M. File S.56428/II.

meteorological cyphers also tended to tilt the balance in favour of relaxation wherever it was justifiable. During the first year or so considerable confidence was felt in their security, but as experience was gained, the experts' estimate of the amount of traffic the cyphers could carry with safety became steadily lower. At the same time, as an adequate meteorological organisation was developed in an overseas theatre where land-line communication was non-existent or impracticable, the amount of wireless traffic increased steadily. The choice was then one of introducing a more complex cypher system with its attendant difficulties of distribution and operation, or of transmitting reports from certain areas in clear and conserving the cyphers for the areas in which it was more important to maintain full security.

At the meeting on 20 January 1943, the Admiralty representatives considered that as full meteorological security as possible should be maintained, quoting in support of their views the statements of a German meteorological officer, captured on a raider, which showed that the existing arrangements were generally effective. The Air Staff view was that security should be relaxed as far as permissible in view of the many complaints of delays, caused by the necessity for encyphering all meteorological messages, which had been received from the authorities concerned with the delivery routes to the Middle East. The possibility of keeping the main collective broadcasts in cypher while permitting the collection of individual reports and transmissions to aircraft in clear was considered but rejected as the signals security representative felt that the transmission of the same reports in clear and in cypher would compromise the latter if the enemy were able to intercept some of the in-clear reports. Finally, the following compromise was reached :—

(*a*) Forecasts and reports of observations transmitted by radio should be encyphered if they referred :—

(i) to the area north of 20° N.

(ii) to the land area within 50 miles of the coast of Africa,

(iii) to adjacent oceans, seas and islands including the whole of Madagascar.

(*b*) Reports of meteorological observations from land stations more than 50 miles from the coast of Africa and south of latitude 20 N. need not be encyphered except for the islands of (*a*) (iii). Reports from aircraft over, or forecasts for this derestricted part of Africa need not be encyphered.

This policy was put into effect on 25 January 1943. In the case of South Africa, the local authorities decided to widen the coastal strip to approximately 100 miles, to include the Coastal Command area. In the other areas the decisions of the meeting were put into effect as agreed.

The compromise between the naval and air points of view devised at this meeting viz., a 50-mile meteorological security strip next to the coast and a non-security area inland, was adopted by the British authorities on a number of later occasions, whereas the compromise of maintaining collective transmissions in cypher while permitting the transmission of individual reports in clear, which was rejected, was later adopted in the United States, and was the cause of lengthy controversies and representations between the two countries.

The Red Sea and Saudi Arabia

The derestricted area of Africa was extended on 25 August 1943 to include the central Red Sea area and the greater part of Saudi Arabia. This action originated in a suggestion by the Naval C.-in-C. Levant, made at the end of June, that the transmission of reports from coastal stations in the Red Sea area, and in particular from Massawa and Jeddah, would be speeded up if the reports could be issued in clear. At the beginning of August the Admiralty recommended to the Air Ministry that this suggestion should be accepted. The Air Ministry considered that the suggested derestricted area might usefully be extended to include most of Saudi Arabia, as negotiations were in progress to obtain reports from the interior of that country, and it was thought that the transmission of the reports in clear would simplify matters. After discussion with the Admiralty it was agreed to derestrict the area defined by the line joining the following points :—

15° N. 35° E., 25° N. 35° E., 25° N. 38° E., 30° N. 38° E., 30° N. 45° E., 25° N. 45° E., 25° N. 48° E., 15° N. 48° E., 15° N. 35° E.

The Aden area and the Canal Zone thus remained meteorological security areas but the Central Red Sea and the greater part of Eritrea and Saudi Arabia were derestricted.

The United States and Central Canada

By September 1943 the United States authorities had begun to consider the relaxation of restrictions in the Western Hemisphere, mainly because of pressure from the Army, Air Force and the various air lines,and from agricultural interests. The Admiralty and Air Ministry were informed on 17 September 1943, by the Meteorological Liaison Officer in Washington, that the U.S. Joint Chiefs of Staff had agreed that the Caribbean Defence Command area and Mexico could be derestricted at once, and that further relaxations in the United States and Canada were contemplated.[1]

Further information regarding the United States intentions was received on 23 September. They were, briefly, to permit the transmission of one or at most, two station reports by W/T in clear, whether to aircraft or to a collecting centre, and to recommence broadcasting general forecasts but without mentioning pressures, the condition of the sky, visibility or wind direction. The reasons given were that ' delays caused by encypherment and restrictions on radio broadcasts are more detrimental than advantageous to the war effort, problems of pilot training, transportation by rail, air, highways, critical agricultural activities particularly livestock, protection of vital war activities from storms, cold waves, etc.' The modification or cancellation of meteorological security measures in Greenland, Alaska and other outlying bases were also mentioned. It was reported that the United States Joint Meteorological Committee had recommended that ' this policy, in so far as it will affect security of weather information in Bermuda, Iceland, the Maritime Provinces of Canada and other areas under Allied control, be referred to the Combined Meteorological and Combined Security Committees for consideration and recommendation.'[2]

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[1] In this case, and in all subsequent cases of derestriction involving sea areas, such ships' reports as were received from the derestricted area were still issued in cypher, not for meteorological security reasons, but to avoid disclosing the movements of ships.

[2] A.M. File S.56428/II.

These developments were considered on 1 October 1943, at a meeting attended by the Director of Intelligence (Security) and representatives of Signals, Security and the Naval Meteorological Branch of the Admiralty. It was agreed that two main dangers in the United States' proposals were that the enemy would intercept some at least of the in-clear transmissions and obtain weather information of direct use to him for forecasting and operational purposes, and that he would use this information to break the cyphers in which the U.S. collective broadcasts were made and so obtain important information from other areas, which would enable him in turn to break other cyphers and so on. The policy agreed at the earlier meeting on Africa, that the only satisfactory solution was a clear cut division between an area of complete security and a non-security area, was reaffirmed. In view of the desire in the United States for as much relaxation as possible, it was agreed to recommend that all meteorological reports and forecasts issued by W/T or R/T must be encyphered in a secure cypher if they referred to the area east of a line along the 80° W. meridian as far south as 40° N., thence to a point 30° N. 90° W., then south along the 90° W. meridian to meet the boundary of the Caribbean Defence Command,[1] and that all meteorological information referring to the area west of this line could be issued in clear. As regards the other areas mentioned, it was agreed that Alaska was primarily a matter for the United States, but that reports from Iceland, Bermuda, Greenland and Canada east of 80° W. must remain in cypher. The decisions of the meeting were signalled on 7 October 1943 to the Admiralty and Air Ministry Meteorological Liaison Officers in Washington.

In spite of the British representations and of strong Canadian protests, the United States authorities decided to bring the U.S. Joint Meteorological Committee's recommendations into force from 1 November 1943. It became clear that the move towards partial relaxation was stimulated from a high level and that internal politics played no small part in the decision. It was also stated that political consideration ruled out the possibility of differentiating between one part of the United States and another, as had been suggested in the British counter-proposals.[2]

In view of the United States' action, the Canadian authorities decided to modify the meteorological security arrangements in their area. After consulting the British authorities, security was partially relaxed in the area between Montreal and the coastal range of British Columbia from January 1944, the new regulations in that area corresponding approximately to those in force in the United States, but full security was maintained east of Montreal and in the coastal strip west of the western coastal range. In the partial-security area the transmission of reports to aircraft in clear was permitted, but cypher continued to be used for station reports transmitted by W/T to a collecting centre.

Partial relaxation in the United States was now a *fait accompli*, but the British authorities were so perturbed about the possible effect of the system on the security of the meteorological cyphers that they put forward the more drastic suggestion that the eastern coast-line of the United States should become the division between the complete security area of the Atlantic and Eastern Canada and the non-security area of the United States, and that all meteorological information referring to the latter area, including collectives, should be

[1] Roughly along the line of the Alleghanies in the United States.

[2] A.M. File S.56428/II.

broadcast in clear. This suggestion was considered by the Combined Meteorological Committee in Washington on 14 December 1943, but neither the United States nor the Canadian authorities felt that the in-clear broadcasting of United States collectives was justified. It was agreed, however, that the consecutive editions of the main U.S. meteorological cypher should be used first for broadcasts of data from the complete security areas, and then, after an interval, for the collective issues of reports appertaining to the United States. It was argued that the security areas would thus be kept completely secure, and the enemy would still be faced with considerable difficulties in obtaining data from the United States. The British authorities considered that the enemy would have little difficulty in breaking the cypher during its second period of use, and regarded the arrangement as being of little hindrance to the enemy, while the delays inherent in the use of the cypher continued to handicap the Allies, particularly for transatlantic flying operations. They therefore continued to urge the use of a separate cypher, or for the issue of the United States data in clear. After the matter had been fully discussed in this country with a Canadian meteorological representative it was, however, agreed not to press for the collective broadcasts to be made in clear, but to continue to press for the use of a secure cypher, as, in the view of the cypher experts, the breaking, even in arrear, of a cypher which had been used in a secure area would give the enemy useful information about the contents of allied meteorological broadcasts which would in turn help in the breaking of other cyphers. In order to avoid distribution difficulties it was suggested that the odd numbered editions of the U.S. meteorological cypher should be used for the complete security area, and the even numbered editions for the partial security area of the United States. This suggestion was accepted in principle by the United States authorities towards the end of February 1944 and was put into effect that summer.

Surface Reports at Gibraltar

While the controversy regarding reports from the United States was in progress consideration had been given to relaxing meteorological security in a number of other areas. Gibraltar was the first of these. The reports from Gibraltar had been encyphered from the outbreak of war in conformity with the general policy for the Mediterranean, in spite of the fact that Spanish reports were broadcast in clear and that the enemy could be expected to have access to reports from Tangiers. Security at Gibraltar had been imposed and maintained on the grounds that the weather conditions around the Rock were often very local and there was no known Spanish reporting station in the neighbourhood. It became known, however, that the enemy were obtaining reports from a station in Spain in the immediate vicinity of the North Front Airfield and, with the agreement of the Admiralty, it was decided to permit the transmission of surface weather reports from Gibraltar in clear, while maintaining the use of cypher for other weather information such as forecasts, upper air reports and reports from the meteorological flight based on Gibraltar. This measure, which was primarily intended to ease the task of aircrews landing at Gibraltar, was put into effect on 1 October 1943.

The South Atlantic

Attention was focused on the South Atlantic in November 1943 when H.Q. European U.S.A.T.C. suggested that weather reports on the South Atlantic air routes should be broadcast in clear. After consulting the Admiralty

a reply was sent that, as the Naval situation had not materially changed, no change in the existing procedure should be made. There appears to have been some uncertainty at this time regarding the actual procedure in the South Atlantic, particularly on the islands of St. Helena and Ascension in which the U.S.A.T.C. were very interested in connection with the southern transatlantic routes. At the end of December 1943, A.H.Q. West Africa stated that the U.S.A.A.F. had received authority to issue reports from these two islands in clear. When the M.O. Liaison Officer in Washington investigated this, it was stated to be part of the new U.S.A.A.F. regulations regarding general security on non-tactical flights ; and that the U.S. Navy were prepared to agree to the use of plain language in the North and South Atlantic west of a line which would include the Azores and the West African coast below Rabat Sale. A further signal from Washington a few days later (mid-January) stated that the U.S. War Department had authorised the discontinuance of weather security in the South American theatre. This theatre was stated to include Ascension but not St. Helena and, according to the signal, the U.S. authorities concerned had been informed that weather reports from the latter must be issued in cypher. Still another version was contained in a letter from H.Q. European Wing U.S.A.T.C. dated 31 January 1944, which quoted a letter from Washington stating that the transmission of weather information in clear in the South Atlantic had been authorised by the U.S. Joint Chiefs of Staff from 15 October 1943 when the decision was taken regarding the Caribbean Defence Command.[1] In view of these conflicting statements and of the fact that meteorological security was maintained in the area in question to meet the wishes of the Admiralty, the question was referred to the latter before pursuing it further. It was agreed to discuss this problem and that of Africa and the Middle East at a meeting at the end of March when the Admiralty had obtained the views of the Naval C.s-in-C. concerned. The decisions of the meeting are dealt with in a subsequent paragraph.[2]

Further Derestriction in Africa, Middle East and the Atlantic

During 1943 the war situation in the Mediterranean had undergone a radical change. The successful completion of the North Africa and Sicily campaigns and the establishment of a firm hold on Southern Italy called for a review of the merits of maintaining meteorological security in the countries adjoining the Mediterranean basin, and in November 1943 the Naval Meteorological Branch were asked for the Admiralty reactions to such a suggestion. As it appeared that the Admiralty would be prepared to agree to considerable relaxation, Headquarters M.A.A.F. and R.A.F. Middle East were asked for their comments on several alternative proposals. The consensus of opinion was that complete relaxation of meteorological security measures could be permitted in Africa south of 30° N., Transjordan, Iraq, Persia and the Persian Gulf and Arabia apart from a coastal strip bordering the Indian Ocean.

The possibilites of relaxation in Africa, the Mediterranean and Middle East and also in the South Atlantic were discussed on 21 March 1944 by Air Ministry

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[1] The actual decision as notified to the 25th meeting of the Combined Meteorological Committee referred to the Caribbean and to the South *American* theatre.

A.M. File S.56428/II.

and Admiralty representatives who agreed that the balance was now in favour of transmitting in clear forecasts and reports which referred to the following areas :—

(*a*) Africa south of 30° N. except for a coastal strip 100 miles wide from 20° S. on the west coast round the Cape and up the east coast to the southern boundary of Portuguese East Africa, and a coastal strip 50 miles wide from the northern boundary of Portuguese East Africa to 15° N.

(*b*) Islands in the Atlantic between 30° N. and 20° S.

(*c*) Arabia except for a coastal strip 50 miles wide bordering the Indian Ocean from Hodeida to Ras el Hadd inclusive.

(*d*) Transjordan.

(*e*) Iraq.

(*f*) Persia and Baluchistan west of 65° E.

It was decided to derestrict the areas (*a*) to (*e*) from 1 April 1944 but to obtain the views of the Russian authorities before taking action regarding area (*f*).

The first reaction of the Russian authorities, who were consulted through 30 Mission, was that it was preferable to maintain security in Persia, but they later agreed to a compromise that Persia south of 35° N. should be derestricted, while security was maintained in Persia north of 35° N.[1] Persia south of 35 ° N. apart from a coastal strip 50 miles wide from Bandar Abbas eastwards was derestricted from 10 June 1944.[2]

A somewhat unexpected protest regarding the derestriction of the Persian Gulf was made by the United States authorities on the grounds that there was considerable submarine activity in the area. The main justification for the decision was that weather in the Persian Gulf is very seasonal, conditions varying very little from day to day, and that reports from stations in the Gulf do not materially assist in constructing a synoptic chart covering the Indian Ocean.

The Falkland Islands and South Georgia

The Falkland Islands and South Georgia were derestricted from 20 June 1944, owing, apparently, to a request by the Brazilian authorities for these reports. The Brazilian authorities had been co-operative in supplying their reports to the British naval meteorological offices in the area, but the Brazilian meteorological cypher was very weak, and it was felt that it would not be possible to reciprocate without grave danger of the reports and the British cypher being compromised. The alternative of derestricting the reports appears to have been adopted as the most satisfactory solution.[3]

Relaxations of Security nearer Main Theatres of Operations

The relaxation of meteorological security restrictions in the areas already described naturally gave rise to suggestions that a number of other areas might be derestricted. In March 1943 the Joint Meteorological Committee in India proposed to the Headquarters of the Supreme Commander, South-East Asia, the introduction of partial meteorological security (on the lines of that

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[1] The meteorological stations in Persia manned by British personnel were, with two exceptions, south of 35° N. The Russian-manned stations were north of this line.

[2] A.M. File S.56428/II.

[3] Composed of representatives of the India Meteorological Department and the Chief Meteorological Officer and Air Staff of Air Headquarters. (A.M. File S.56428/II, Encl. 198C.)

in force in the United States) in that part of India lying to the west of a line joining Mangalore, Bangalore, Hyderabad (Deccan) and Allahabad and thence northwards along the 83° E. meridian, and in the adjoining land and sea areas bounded on the south by the 15° N. parallel and on the west by the 45° E. meridian. The main reason for this proposal was the usual one of difficulty in communicating meteorological information to aircraft in cypher, aggravated by poor communications and the employment of native personnel. It was urged that although the Japanese would be able to intercept occasional reports from Western India, this information would add little to what they already knew from their geographical position and the normal seasonal changes. The proposals were approved by the Headquarters of the Supreme Allied Commander, but as the Air Ministry signals security experts were opposed to the principle of partial security and the Admiralty indicated that the proposals were not acceptable to them, the matter was not pursued until the beginning of 1945 when meteorological security in India was reconsidered as part of a more general review.[1]

In July 1944, and again in September, it was suggested that South Africa and the surrounding sea areas might become non-security areas in view of the decreasing submarine menace. These suggestions were also incorporated in the more general review mentioned in the preceding paragraph.

The most striking suggestion regarding the abolition of meteorological security instructions made about this time was made on 21 May 1944 by D.M.O. to D. of I.(S). D.M.O. suggested that England, south of a line from Bristol to the Wash, might possibly be made a non-security area and summarised the pros and cons of the proposal. The suggestion had been made as the result of representations from various quarters including H.Q. SHAEF, and D.M.O. asked that it should be put to the Chiefs of Staff for a decision as a matter of immediate importance, as operational staffs tended to assume that the decision to keep meteorological information secret was made a long time ago when we were on the defensive and that it no longer applied in any strict way to the present circumstances. (A growing body of opinion considered that meteorological security was a purely defensive measure which was no longer necessary when the Allies were on the offensive. This view was expressed on a number of occasions throughout 1944 until the German Ardennes offensive demonstrated how a defending force could make use of the weather to offset the overwhelming air superiority of an opponent, to move and concentrate forces with impunity, and to launch a counter-offensive without the risk of strong intervention by the opposing air forces.) The proposal to derestrict Southern England was still under consideration when the Allies landed in North-West Europe and when the first flying bombs fell on England. It was then shelved until the characteristics of the new weapon could be more fully studied. The question was re-opened by H.Q. SHAEF in December 1944 and by H.Q. Transport Command in April 1945 but on each occasion it was decided that the balance was in favour of maintaining the security regulations and England remained a full meteorological security area until the end of hostilities in Europe.

North Africa and the Southern Mediterranean

While the possibility of derestricting Southern England was being debated, the war situation in the Mediterranean had improved still further. By the end of August 1944 the Allies had pushed past Rome to Florence and had made

[1] A.M. File S.101175.

successful landings in Southern France. The increasing air traffic along the North African coast made it difficult to maintain effective meteorological security and there appeared to be a strong case for further relaxation in that area. At the end of August it was decided to ascertain the views of H.Q. R.A.F. M.E., H.Q. M.A.A.F., and the Admiralty on the possibility of relaxing the meteorological security restrictions for the whole of North Africa. The two Commands agreed, but the C.-in-C. Mediterranean said he could not accept the suggestion until the air threat to shipping off the North African coast was ended. The matter was therefore dropped until mid-October, when notification was received that the C.-in-C. now agreed. Meteorological security restrictions were consequently cancelled in Africa north of 30° N. and in Palestine and Syria with effect from 1 November 1944.

Further deristrictions in the Mediterranean area followed rapidly. At the beginning of November, H.Q. R.A.F. M.E. suggested that the Turkish authorities should be asked to recommence their meteorological broadcasts in clear to facilitate the operation of the B.O.A.C. service which was being inaugurated between Cairo and Ankara. There was some delay in putting this suggestion into effect as the U.S.S.R. was first consulted and it was not until the end of December that the in-clear broadcasts began. In the meantime, reports from Cyprus were issued in clear from 23 December 1944. At the beginning of January 1945 the Admiralty suggested that meteorological security should be relaxed on the sea route from Gibraltar to Port Said and it was agreed that forecasts referring to the sea area south of 38° N. in the Western Mediterranean and south of a line joining Cape Passaro to Port Said in the Eastern Mediterranean, should be issued in clear from 15 January 1945. Surface reports from Malta were issued in clear from the same date but upper air information referring to the island remained in cypher. Five days later, the Eastern Mediterranean east of 30° E. was declared an in-clear area for weather reports from aircraft—the last change in the meteorological security regulations in the Mediterranean area until the final relaxation when hostilities in Europe ceased.

North-West Europe

In June 1944, when it was agreed to drop the question of derestricting Southern England because of the flying bomb attacks, H.Q. A.E.A.F. recommended that the transmission of meteorological reports from the immediate battle area, within a belt 25 miles wide on the Allied side of the front line, should be permitted in clear. It was urged that this would have substantial advantages, both in saving time and in avoiding corrupt messages. The Air Ministry raised no objection to this proposal, provided certain precautions were taken to ensure that the meteorological cyphers were not compromised by subsequent transmission of the reports in cypher, but it was pointed out that the enemy would be provided with almost continuous reports of the weather over the military area, and it was therefore suggested that H.Q. 21st Army Group should be consulted before the proposals were implemented. Apparently the Army Authorities were not prepared to agree to the suggestion as no further action was taken to put the proposals into effect.

There remained, however, a strong body of opinion, particularly in the Allied Air Forces, which considered that the existing meteorological security regulations were unwarranted at the stage which the war had reached, and at

the end of July a draft H.Q. SHAEF directive was circulated to the various Commanders-in-Chief and Commanding Generals, in which it was proposed to authorise the transmission of meteorological observations from the operational area by wireless in clear. There appears to have been considerable opposition to this step as the suggestion was not pursued. In December the problem was re-examined at a high level in the Air Staff and at H.Q. SHAEF and again the suggestion that essential weather information was being denied to operational formations and units by 'an exaggerated degree of secrecy' was rejected.

Finally, H.Q. SHAEF, acting on their own initiative, authorised the transmission in clear by wireless of reports from stations, other than coastal stations, in the area east of 4° E. and from airfields in the Paris area, with effect from 10 January 1945. The derestriction did not, however, apply to analyses, inferences and forecasts which continued to be issued in cypher. Although the derestriction introduced by H.Q. SHAEF facilitated the communication of weather reports to aircraft in the forward areas and on the U.S.A.T.C. transport routes through France to the Mediterranean, the main R.A.F. Transport Command routes across France remained in a security area, and H.Q. R.A.F. Transport Command requested on 21 April 1945 that meteorological security restrictions should be cancelled in Southern England, the whole of France, Corsica, Sardinia, Sicily and Italy up to 43° N. The question of France and Southern England had been considered at a meeting on the previous day as a result of an earlier request from Transport Command that the transmission to aircraft of weather reports from Manston, Northolt, Ford, Lympne and Gatwick should be permitted in clear. In deference to the views of the Admiralty representatives, it had been agreed that no exceptions could be made in Southern England, which must remain a security area, but it was agreed that, subject to the concurrence of H.Q. SHAEF, meteorological reports referring to France west of 4° E., except those referring to a 25-mile coastal strip along the Channel and the Atlantic and Mediterranean seaboards, could be issued in clear. These proposals, which represented a considerable step towards fulfilling the request of Transport Command, were agreed by H.Q. SHAEF, and were put into effect on 6 May 1945. By this time events in Europe were moving very rapidly and the complete removal of meteorological restrictions followed a few days later.

Russia

Until the end of 1944 the Russian authorities had indicated no wish to relax their meteorological security restrictions; indeed they appeared to wish to maintain security in areas in which the British authorities considered it was no longer justifiable, *e.g.*, Persia, and they were averse to discussing a common plan for co-ordinated action when hostilities in Europe ceased. At the beginning of December 1944, however, they requested the British views on a proposal to derestrict the area between 60° E. and 110° E. with the exception of the shores of the northern seas. The Air Ministry welcomed the proposal and in January the Russians stated that they would put the proposal into effect from 1 February 1945 for the area between 54° E. and 100° E. There appears to have been a slight delay, however, as it was not until the end of the first week of February that the reports from that area were actually issued in clear.

South Atlantic, South-East Africa, Indian Ocean and South-East Asia

While the above developments were taking place in Europe, the question of the Indian Ocean and the adjoining land areas was reopened. In December 1944 H.Q. R.A.F. Middle East urged that the Gulf of Aden and the coastal areas in Southern Arabia and East Africa should be derestricted, if possible, before 1 January 1945 in order to avoid the necessity of introducing a new ground-air cypher in that area. The Admiralty were then reviewing the need for meteorological war organisation in the various naval stations from the South Atlantic to India, but, in view of the reasons behind the request from H.Q. R.A.F. M.E., they agreed to introduce the limited relaxation suggested without waiting for the results of the general review. The Gulf of Aden and coastal strips in East Africa and Southern Arabia were therefore derestricted from 1 January 1945.[1]

Admiralty and Air Ministry representatives considered the more general problem on 11 January 1945, and agreed that meteorological security restriction could be removed in the following areas, provided arrangements were made to re-introduce them at very short notice:—[2]

(*a*) The coastal strip of Africa south of 20° S.

(*b*) The South Atlantic Ocean and islands in it south of 20° S.

(*c*) The whole of India except Bengal, Assam and a strip 50 miles wide along the east coast of India from Cape Comorin northwards.

(*d*) The 50-mile strip along the coast of Persia and Baluchistan.

(*e*) The Indian Ocean south of 25° S. and west of 45° E.

Although the air transport routes across Africa and from the Mediterranean to India were now freed from meteorological security there was continued pressure for further relaxations in those parts of the South-East Asia theatre which remained security zones. In mid-February the Allied Meteorological Committee in South-East Asia,[3] after consulting the service authorities in the theatre, recommended that relaxation should be extended to include the whole of India, Ceylon and the Indian Ocean west of 82° E. In April, the Admiralty indicated that they had no objection to the derestriction of India, but suggested that the question of the Indian Ocean should be reconsidered in consultation with the Naval C.-in-C. East Indies. As a result of this reconsideration the proposals of the Supreme Allied Command South-East Asia were somewhat modified. Instead of complete derestriction of India and the Indian Ocean west of 82° E., it was suggested that reports and forecasts should be issued in clear, but that analyses, reports from operational aircraft and reports from ships should remain in cypher. These modified proposals were put into effect from 15 May 1945.[4]

Further relaxations followed rapidly as the war situation in South-East Asia improved. From July 1945 the area defined in the previous paragraph was extended to include Burma north of 15° N., the Bay of Bengal and the Indian

[1] A.M. File S.101175.

[2] This now made the whole of the Continent of Africa a derestriction area.

[3] Composed of representatives of the India Meteorological Department, the Meteorological Office, A.H.Q.S.E.A., the Naval Meteorological Service, C.-in-C. Eastern Fleet and the Weather Service of the U.S.A.A.F.

[4] A.M. File S.101175.

Ocean west of a line joining points 15° N. 90° E., 00° 90° E., 20° S. 110° E. and then south along the 110° E. meridian.[1] As a result of a Meteorological Conference held in Manila the regulations were further modified, and from 1 August weather messages, with the exception of ships' reports and reports from aircraft whose position it was not wished to disclose, referring to South-East Asia Command west of the following line, were issued in clear :—the eastern boundary of Burma southwards to 15° N., then westwards to 90° E., southwards to the Equator, then to a point 10° S. 100° E. and eastward along the 10° S. parallel. Weather reports east of this line were also issued in clear, but forecasts, analyses and ships' and aircraft reports remained in cypher. These regulations remained in force for the few remaining weeks of the war against Japan, and in view of the uncertain situation were kept in force for a short period after the official end of hostilities. They were finally cancelled on 20 September 1945 when all meteorological security restrictions in South-East Asia were cancelled.

Proposals for further Relaxation in North America and North Atlantic

In July 1944 the United States authorities made a number of tentative enquiries to ascertain the views of other interested parties on a proposal to relax completely meteorological security arrangements in North America and Greenland. The British felt that it was essential to maintain security in Greenland, but that no objection would be raised to relaxation in Canada west of 65° W. provided the Canadian authorities agreed. The matter does not appear to have been pursued then but it was raised again, in more general form, by the Atlantic Joint Control Board of the U.S. Air Transport Command and R.A.F. Transport Command which recommended as great a degree of relaxation as possible in Eastern Canada, Newfoundland, Labrador, Greenland, Bermuda and the North Atlantic generally.

The problem was discussed at a meeting in Air Ministry on 9 October 1944 at which the Admiralty and the Canadian Meteorological Service were represented. The Canadian representative was at that time acting as Senior Meteorological Officer, H.Q. 45 Group and his views were therefore closely associated with those of R.A.F. Transport Command. It was agreed that no relaxation should be permitted in Greenland, Bermuda, or the North Atlantic, but there was a divergence of views regarding Eastern Canada, Newfoundland and Labrador. The arguments put forward by the three services were briefly :—

Canada—

(*a*) The introduction of limited meteorological security, *i.e.*, the transmission of reports to aircraft in clear, would greatly ease the work of transport and other aircraft.

(*b*) Limited security was in force in the United States as far north as Preaque Isle and, therefore, there was little to be gained by retaining full security in Eastern Canada.

(*c*) The U.S.A.A.F. station in Canada already transmitted a large amount of meteorological information in clear as they interpreted the word ' emergency ' very freely and sent reports in clear when the cloud was below 1,000 feet and the visibility less than 3 miles.

[1] Meteorological security regulations east of this meridian were the concern of the Australian Meteorological Service.

(*d*) The R.C.A.F. anti-submarine patrols did not normally operate from bases from which reports were likely to be intercepted.

(*e*) Reports from three or four stations only would be intercepted by the enemy occasionally at night and it would not be possible to make accurate forecasts on these reports.

Admiralty—

(*a*) Any arrangement which permitted regular interception by the enemy of reports from Eastern Canada and Newfoundland would be unacceptable.

(*b*) The Admiralty might be prepared to agree to limited security provided they were convinced that only occasional reports would be intercepted and that other services would gain a substantial advantage by the introduction of limited security.

Air Ministry—

(*a*) Reports from Eastern Canada and Newfoundland would be of appreciable value to the enemy for forecasting in Europe, and would be of great value for Atlantic forecasting.

(*b*) The existing ruling of the Chiefs of Staff was that meteorological security was necessary over the Atlantic and in Europe, and therefore regular services of meteorological information must be denied to the enemy.

(*c*) The above considerations must be balanced against the fact that the limited security conditions which would obtain in Canada if the proposal were agreed, already obtained in the United States and Central Canada.

In view of these differences of opinion it was agreed to refer the matter to the Director of Intelligence (Security) in the Air Ministry, but before this could be done the A.O.C.-in-C. Transport Command had raised the question personally with the Chief of the Air Staff. Further discussions at a high level between the Admiralty and Air Ministry followed, and in deference to the Admiralty views it was decided to oppose the proposed relaxation in Eastern Canada and Newfoundland. In the meantime it was learned that the Canadian Chiefs of Staff were also opposed to the suggestion, but in February the U.S. Chiefs of Staff pressed the matter further in the Combined Chiefs of Staff Committee. It was then referred to the Combined Meteorological Committee for further examination and the matter was still under discussion when the end of the war in Europe resolved the deadlock.

The End of the War in Europe

In August 1944, when the break-through in France and the Russian advances gave promise of an early German collapse, D.M.O. suggested preparing in advance a co-ordinated Allied plan for the cancellation at the end of hostilities of meteorological security regulations in those areas which affected forecasting within the European theatre of operations. Draft proposals, including a list of the areas affected, were agreed with the Director of the Naval Meteorological Service and the Director of Weather Services U.S.S.T.A.F. and submitted to the British Joint Chiefs of Staff. As the areas specified included Western

Russia it was decided to forward the proposals to the Combined Chiefs of Staff with a request that, if the plan was agreed, the concurrence and co-operation of Russia should be sought.[1]

The list of areas in which it was suggested that meteorological security restrictions should be lifted, as submitted to the Combined Chiefs of Staff on 7 September 1944, was :—[2]

(*a*) All Europe.

(*b*) All Asia west of 60° E., except the coastal strip of Persia 50 miles wide from Bandar Abbas to 60° E., and the coastal strip of Arabia 50 miles wide from Hodeida to Ras el Hadd.

(*c*) All Africa except the east coast strips, viz., the coastal strip 100 miles wide from the Cape of Good Hope to the southern boundary of Portuguese East Africa, and the coastal strip 50 miles wide from the northern boundary of Portuguese East Africa to 15° N.

(*d*) All inland seas enclosed in the above areas including the Red Sea and the Persian Gulf.

(*e*) The North Atlantic and Arctic Oceans west of 60° E.

(*f*) The South Atlantic and Antarctic Oceans west of 18° 30 E.

(*g*) Greenland.

It was also stated that the British authorities would regard it as advantageous if meteorological security was lifted in North America east of the Rockies, but left the precise western limit to be agreed between the United States and Canada.

It was recommended that, if the Combined Chiefs of Staff agreed, they should seek Russian co-operation and that the executive decision to cancel the restrictions should be given by the Combined Chiefs of Staff. This latter proposal later gave rise to some misunderstanding between the United States and British authorities, for, when the plan was subsequently shelved by the Russians, the British view was that they were free to take independent action as they had done hitherto, whereas the United States authorities apparently considered that a Combined Chiefs of Staff decision should be obtained before permitting any relaxation of meteorological security regulations at the end of the war in Europe.

The proposals were approved by the Combined Chiefs of Staff and communicated to the General Staff of the Red Army on 30 November 1944. On 6 January 1945 Soviet General Staff replied that it was too early to consider and decide questions regarding the removal of weather security measures following the defeat of Germany, and that a decision on this matter would depend on the situation which existed at the time of Germany's collapse.

Following the Russian reply the matter was dropped and, as already stated, the British authorities then regarded themselves as free to take independent action. This apparently was also the view of H.Q. SHAEF as a SHAEF directive of 15 April 1945 stated that all meteorological information relating to France, Belgium, Holland, Denmark, Norway and that part of Germany under SHAEF control would be issued in clear either on 'the formal signing

[1] A.M. File S.101175.

[2] It will be noted that the subsequent derestriction of some of the areas, before the end of the war in Europe, has already been described in preceding paragraphs.

by the German Government and/or German High Command of the instrument of surrender, or by formal announcement of the end of hostilities by the Supreme Commander.'[1]

Action to cancel meteorological security regulations in the areas already mentioned followed rapidly on the German surrender, but without the co-ordination which it had been hoped to achieve. The Air Ministry, with Admiralty concurrence, derestricted the United Kingdom, Eire, the Azores, Bermuda, Jan Mayen and the Faroes from 9 May 1945. France, Belgium, Holland, Denmark, Norway and the part of Germany under SHAEF Control were cleared on the same date. Canada and the M.A.A.F. theatre followed suit on 11 May. Sayville, one of the United States wireless stations broadcasting meteorological reports, began transmitting in clear on 9 May but this was apparently in error as it reverted to cypher the next day and it was not until 12 May that the United States, Alaska (except the Aleutians and the peninsula south of 58° N. and west of 158° W.) and Greenland were finally derestricted. Neither in Canada nor in the United States was it considered necessary to maintain security on the western seaboard. The transmission of meteorological data from Russia west of 54° E. and from Russian-occupied Eastern Europe began on 14 May,[2] thus completing the derestriction of Europe, North and South America, the North and South Atlantic, the North Sea, Africa and the Near and Middle East. Ships' reports were the one exception to the complete security relaxation in these areas, as it was necessary to maintain secrecy regarding the positions of ships until the intentions of the U-boats became clear. By the end of May the Admiralty were satisfied on this score and instructions were issued permitting the transmission of ships' reports in clear from 29 May, the date on which the maintenance of wireless silence by ships in the areas in question was cancelled. The instruction regarding the transmission of meteorological reports in clear was countermanded, however, as the result of representations by the United States authorities, and it was not until 7 June that the transmission of these reports in clear was finally authorised.

Relaxation in the Pacific

Only a very brief outline is given of the various stages of relaxation of meteorological security in the Pacific, as the American authorities granted their local C.s-in-C. a much greater degree of autonomy in these matters than was the normal British practice, and it was only in connection with the South-West Pacific area that British views were sought. As the weather in that area had a bearing on the weather in the Indian Ocean, the Director of the Australian Meteorological Service, who acted as Chief Meteorological Officer S.W.P.A., referred any proposed changes in the South-West Pacific to the Meteorological Office for comment before taking action.

Relaxation in the Pacific was first suggested in June 1944 when the C.-in-C. proposed that security regulations should be modified east of 165° E. This raised the question of relaxation in the South-West Pacific and, in reply to a query from Australia, it was stated that there was no British objection to relaxation south of the Equator and east of 160° E. The matter was discussed by the Combined Meteorological Committee on 4 August 1944, and it was agreed

[1] A.M. File S.101175.

[2] Meteorological security restrictions were maintained in Russia east of 100° E. until the end of the Japanese War.

that with the exception of forecasts and analyses, ships' reports and reports from certain aircraft, weather information should be transmitted in clear south and east of a line from the west coast of South America along the Equator to 165° W., then to 15° S. 175° E., 25° S. 175° E., along the 25° S. parallel to the coast of Australia, round the east and north coasts of Australia to 138° E., then to 20° S., 138° E., along the 20° S. parallel to 110° E. and south to the Pole.

As a result of representations from the Admiralty and the C.-in-C. Eastern Fleet that coastal reports from Western Australia would provide the enemy with valuable data for forecasting in the East Indies area and would jeopardise Indian Ocean shipping routes to Australia, the western boundary of the area was amended to 125° E. before the new procedure was put into effect on 15 September 1944. At the end of November the C.-in-C. Eastern Fleet indicated that he would no longer object to the western boundary of 110° E., and the change to 110° E. was made at the beginning of January 1945.[1]

At the end of March 1945, the Commanding General S.W.P.A. and the C.-in-C. U.S. Pacific Fleet recommended that the northern boundary of the limited security zone in their area should be amended to run from 15° S. 175° E. to 0° 159° E., south to 10° S. 135° E. and west to 10° S. 110° E. At the 72nd meeting of the Combined Meteorological Committee, the latter two points were amended to 20° S. 135° E. and 20° S. 100° E. The C.s-in-C. Eastern Fleet and British Pacific Fleet agreed, and the revised boundary became effective on 15 May 1945.

The C.-in-C. United States Fleet and Pacific Ocean areas made a further modification on 17 April 1945 when he declared the area east of a line from 0° 163° W. to 30° N. 163° W. to 40° N. 124° W. a limited security area in the sense in which that was interpreted in the United States, *i.e.*, not more than two reports could be broadcast in clear but other weather information remained in cypher.[2]

More changes were made in quick succession from the beginning of June 1945. Early in June, the South Pacific east of 82° W. was declared a non-combat area and all weather data from that area, including ships' reports, were issued in clear. From 20 June, the Pacific north of 58° N. and the area east of a line connecting 58° N. 158° W., 30° N. 170° W., 0° 159° E. and then south along the meridian 159° E. were derestricted for all meteorological data, except that ships' reports might still be transmitted in cypher at the commander's discretion. This procedure was extended on 1 July to the South-West Pacific area south of 10° S. North of that line, all data were transmitted in clear except forecasts, analyses, ships' reports and reports from certain aircraft. The C.-in-C. Pacific Ocean areas authorised partial relaxation in the Central Pacific from 10 July when all weather data except forecasts, analyses, upper air data, ships' reports and reports from certain aircraft, were issued in clear if they referred to the area enclosed by the line 20° N. 130° E., 0° 130° E., 0° 159° E., 20° N. 130° E. These regulations were extended on 1 July to the Northern Pacific in the area bounded by 58° N. 159° E., 20° N. 177° E., 30° N. 170° W., 58° N. 158° W., 58° N. 159° E. All meteorological security restrictions were cancelled in the Pacific on 25 August 1945.[3]

[1] A.M. File S.101175.
[2] 74th Mtg. of the Combined Meteorological Committee.
[3] 75th and 76th Mtgs. of the Combined Meteorological Committee.

CHAPTER 33

ORGANISATION AND SUPPLY

Headquarters Organisation

Throughout the war, the administrative headquarters of the Meteorological Office remained in London. The composition of the headquarters unit at the beginning of September 1939 was as follows :—

Director

A.D.M.O. I in charge of
- M.O.1 Marine.
- M.O.3 Climatology.
- M.O.4 Army and Instruments.
- M.O.10 Personnel and General Services.
- M.O.10 Training School.

A.D.M.O. II in charge of
- M.O.2 Forecasting and Civil Aviation.
- M.O.5 Overseas.
- M.O.6 Royal Air Force.

A.D.M.O. III in charge of the office in Edinburgh and the observations at Kew, Eskdalemuir, Lerwick and Aberdeen.

The Branches under A.D.M.O. I, with the exception of M.O.10 (Personnel and General Services), were located at Kensington and the remainder at Victory House, Kingsway. The staff in London before the evacuation of any of the Branches to the provinces was approximately 300, of whom 140 were at the Training School.

During the week before the outbreak of war, a section of M.O.2 was evacuated to Birmingham and became, temporarily, the centre for the preparation of weather forecasts and of the teleprinter network for the collection and distribution of meteorological information. The section which remained in London was connected by teleprinter with the main centre at Birmingham and maintained, day and night, throughout the war, a continuous service of synoptic charts and information as a safeguard against a breakdown of the service at the main forecasting centre as well as for the information of the Director and senior officers in London and for other special purposes.

As a precaution, a quantity of essential meteorological instruments and equipment, equal at that time to about three months' normal issues, was transferred in the last days of August 1939 by the Instruments Branch from the South Kensington office to a store in Cheltenham. During October and November, considerable quantities of important books and records from the Library, marine logs and Hollerith cards from the Marine Branch and further instruments and stores from the Instruments Branch were transferred from South Kensington and Kingsway to Wycliffe College at Stonehouse in Gloucestershire. Finally, the personnel of M.O.1, M.O.3 and M.O.4 were transferred

with the remaining equipment to Stonehouse on 30 November 1939. Despite a number of proposals to move these Branches elsewhere at various stages of the war, they remained at Stonehouse until the end of the war.

The following emergency arrangements were brought into operation on the outbreak of war :—

(*a*) A.D.M.O. III relieved A.D.M.O. I of the responsibility for M.O.1, M.O.3 and M.O.4 and for all matters arising in M.O.10 other than those connected with personnel.

(*b*) Sir George Simpson, K.C.B., F.R.S., the former Director of the office, resumed active duty and, with his headquarters at Kew Observatory, undertook the direction of the work of the observatories and the office at Edinburgh.

(*c*) Duty rosters were brought into operation in all branches at Headquarters which provided for a nucleus of essential staff throughout the 24 hours. On 8 September 1939, this was reduced to the attendance of a Duty Officer outside normal office hours, with two assistants on Sundays.

(*d*) A liaison officer was posted for duty with the Office Nationale Meteorologique in Paris and later in September 1939 an officer from Paris took up a similar position in London.

A senior officer from the headquarters staff was commissioned in the R.A.F. in October 1939 with the rank of Group Captain, as Meteorological Officer-in-Chief in the Field, with the responsibility for meeting all meteorological requirements of the Army and R.A.F. in the Field. Another was commissioned as Wing Commander for liaison duties in London on all R.A.F.V.R. questions. In the following month, the responsibility for meeting the requirements of the Army was transferred from M.O.4 to M.O.5 (Overseas Branch). When M.O.1, M.O.3 and M.O.4 moved to Stonehouse in November 1939, A.D.M.O. I resumed full control of M.O.10.

Work had meanwhile proceeded on the buildings for the Central Forecasting Office which was to be established at Dunstable. As soon as they were ready for occupation, the section of M.O.2 at Birmingham was transferred to Dunstable. For the remainder of the war, Dunstable functioned as the Central Forecasting Office and the centre of the teleprinter network.

The greatly increased demands by the Royal Air Force for meteorological services made it necessary in March 1940 to limit the responsibilities of M.O.6 to the requirements of Bomber, Coastal and Maintenance Commands and to create a new branch (M.O.7) to provide for the requirements of the other Commands of the Royal Air Force at home.

The importance of the synoptic work was recognised in May 1940 by upgrading to the status of Deputy Director the post of A.D.M.O. II without alteration of duties or of the holder of the post.

A special section for Investigations was created in July 1940 to deal with the many inquiries from the Army and R.A.F. for technical information or advice and in November 1940 it became necessary to make special provision for meteorological work for the Ministry of Home Security under M.O.5.

An increase in the meteorological requirements for delivery flights from the United States and a considerable extension of the requirements of the R.A.F. and of Government Departments dealing with both the offensive and defensive

aspects of the war, made a further measure of reorganisation necessary. A new branch (M.O.8) was formed and relieved M.O.5 of the meteorological requirements of the Army, Army Co-operation Command of the R.A.F., the British Forces in Northern Ireland and the Ministries of Supply and Home Security.

Two new posts of Assistant Director were established in November 1941 to assist in the administration of the operational branches under the Deputy Director, one to be responsible for meteorological requirements at home, and the other for those overseas. The opportunity was taken to revise the nomenclature of the Assistant Directors as follows :—

Assistant Director (Personnel—A.D.M.O.(P)) formerly A.D.M.O. I.

Assistant Director (Climatology and Instruments) A.D.O.M.(C. and I.) formerly A.D.M.O. III.

Assistant Director (Home)—A.D.M.O.(H)—new post.

Assistant Director (Overseas)—A.D.M.O.(O)—new post.

At the same time, certain duties of the operational branches (M.O.5, 6, 7 and 8) which came under the two new Assistant Director posts, were redistributed, M.O.8 assuming responsibility for Fighter and Balloon Commands of the R.A.F. and M.O.6 the Training and Maintenance Commands, leaving M.O.7 to deal with meteorological requirements over the Atlantic, including Iceland and Bermuda.

On 1 March 1942, a new section was formed under the Deputy Director to deal with all questions of security and the codes, cyphers, etc., in use in the Meteorological Service.

M.O.2 became responsible in April 1942 for the arrangements for obtaining the upper air observations in the vicinity of the British Isles and in Iceland, which were used in the daily routine of that branch. In August of the same year, the branch was upgraded to the status of an Assistant Directorate of Forecasting, divided into two branches, one dealing with the manipulation and analysis of the synoptic data and the preparation of forecasts, and the other with the collection of the data and the distribution of reports and forecasts.

At the end of the third year of the war (August 1942) the H.Q. of the Meteorological Office was organised as follows :—

A. *London* .. .. Director.
Deputy Director.
M.O.9—Special Investigations.
M.O.15—Security, Codes and Cyphers.

Assistant Directorate (*Home*) :—

M.O.6 .. .. Meteorological requirements of Bomber, Training and Maintenance Commands of the R.A.F. and of Coastal Command except Nos. 15 and 19 Groups ; transferred Training Schools ; Civil Aviation at Home and in Northern Europe.

M.O.8 .. .. Meteorological requirements of Fighter, Balloon and Army Co-operation Commands of the R.A.F. ; War Office ; British Forces in N. Ireland ; Ministries of Supply and Home Security.

Assistant Directorate (*Overseas*) :—

M.O.5 .. .. Meteorological requirements of the R.A.F. and other British Forces Overseas ; Civil Aviation (other than the N. Transatlantic route and Northern Europe).

M.O.7 .. .. Meteorological requirements of the N. Transatlantic route, including Iceland and Bermuda.

Assistant Directorate (*Personnel*) :—

M.O.10 .. Personnel, training and general non-technical services. (Two sections of M.O.2 were located in London—*see* under B.)

B. *Dunstable* :—

Assistant Directorate (*Forecasting*) :—

M.O.2 (*A*) .. Forecasting and Analysis.

M.O.2 (*B*) .. Synoptic Information ; collection and distribution.

M.O.2 (*B/L*) .. Section in London for liaison duties.

M.O.2 (*S*) .. Section in London. Arrangements for obtaining upper air information.

C. *Stonehouse* :—

Assistant Directorate (*Climatology and Instruments*) :—

M.O.1 .. .. Meteorology over the Oceans.

M.O.3 .. .. Climatology.

M.O.4 .. .. Instruments and Equipment ; supply and development.

The two Assistant Directorates of Personnel and Climatology reported to the Director ; the remainder were under the control of the Deputy Director.

The large advance which had been made in the methods of obtaining upper air data, and their importance to the work of weather forecasting for military operations led, in November 1943, to the establishment of a new branch M.O.2/C in the Assistant Directorate of Forecasting at Dunstable, with the responsibility for the arrangements for obtaining upper air observations and for the development of upper air observational technique and of new methods of analysis. This new branch absorbed the work formerly performed by the section M.O.2(S) in London.

In February 1944, a senior officer was posted for special duty at Supreme Headquarters of the Allied Expeditionary Force.

Recommendations of a committee under Inspector-General of the R.A.F. resulted, in September 1944, in a scheme of partial reorganisation of the operational branches of the office under which two new branches were established (M.O.13 and M.O.14) and the responsibility for the provision of meteorological services in the Assistant Directorates of Home and Overseas was reallocated as follows :—

Assistant Directorate (*Home*) :—

M.O.6 .. .. Bomber Command

M.O.8 .. .. A.D.G.B. (A.E.A.F. and Fighter Command) ; War Office ; Anti-Aircraft Command ; Ministry of Supply.

M.O.14 .. Flying and Technical Training Commands ; Maintenance Command (A.T.A.) ; Balloon Command ; Ministry of Fuel and Power ; Ministry of Aircraft Production ; Short Wave Radio.

Assistant Directorate (*Overseas*) :—

M.O.5 .. .. Overseas ; Colonial Office

M.O.7 .. .. Transport Command ; Civil Aviation.

M.O.13 .. .. Coastal Command ; R.A.F. N.I.

Under this scheme, a civilian section of each of the Branches M.O.6, M.O.7, M.O.13 and M.O.8 was established at the headquarters of Bomber, Transport and Coastal Commands of the R.A.F. and the A.E.A.F. respectively, for the purpose of improving the closeness of liaison with the R.A.F. and the Heads of these branches divided their time between their headquarters offices and the sections at the R.A.F. Headquarters.

By 1945, the headquarters staff had increased from the 160 of September 1939 to approximately 490 of whom 120 were in London, 190 in Dunstable and 180 in Stonehouse.

The 'Security Building' adjoining H.M.S.O., Harrow, was inspected in May 1945 as a possible future home for M.O.1, M.O.3 and M.O.4, and a decision in favour of this site was made soon afterwards. After several changes in plans and delays, the move was eventually made in the last week of August 1945.

Committee on Meteorological Services

It was suggested in 1943 that the Royal Air Force should have its own meteorological service. The Secretary of State appointed a committee consisting of Air Chief Marshal Ludlow-Hewitt (chairman), Sir Edward Appleton and Mr. W. A. T. Shorto to examine and report on the proposal.

In their report, the Committee recommended that a separate meteorological service of the Royal Air Force should not be established. They advocated that all Meteorological Office personnel serving with operational units of the R.A.F. should be militarised, but leaving technical control in the hands of the Director of the Meteorological Office. A number of recommendations on other points were made, such as the importance of resuscitating the R.A.F. Meteorological Policy Committee, the revision of King's Regulations to make them conform to modern meteorological requirements, and the appointment of a Meteorological Adviser to each Command Headquarters, and the desirability of encouraging forecasting officers to acquire air experience. The recommendations of the Committee were approved by the Air Council and were implemented early in 1944.

Recruitment and Training of Staff

War-Time Recruiting and Grades

On the outbreak of war, the Meteorological Office was civilian and graded in accordance with the recommendations of the Carpenter Committee. The numbers in the various grades on 1 September 1939 were as follows :—

Directorate	4
Principal Technical Officer and Superintendent	8
Senior Technical Officers	20
Technical Officers and Assistants I	161
Assistants II	193
Assistants III	136

A small Meteorological Branch of the R.A.F.V.R. had been approved before the war for service overseas, but arrangements to recruit the personnel had hardly begun when war broke out.[1]

In order to meet growing R.A.F. requirements at home, advertisements had been issued in August 1939 for unestablished Assistants III and II, with prescribed peace-time age and educational qualifications. Applicants were not interviewed until after the outbreak of war and were designated Temporary Assistant III and Temporary Assistant II. New war-time grades of Meteorological Assistant and Temporary Forecaster Grade II were introduced in October 1939. The duties corresponded generally to those of Assistant III and Assistant II but the minimum educational qualifications were somewhat reduced. In 1941, Temporary Forecasters Grade II were designated Meteorologists Grade II and the grade of Meteorologist I was introduced. A grade of Senior Meteorologist (war-time equivalent of Senior Technical Officer) was introduced in 1943.

Between September 1939 and June 1940, the following were recruited :—

Temporary Assistants III ..	260 (together with Meteorological Assistants)	Temporary Assistants II ..	220 (together with Temporary Forecasters II)
Meteorological Assistants ..		Temporary Forecasters II..	
Other Ranks R.A.F. ..	240	Officers R.A.F.	85

Recruitment was then suspended, but was resumed in January 1941 in both civilian grades and in the ranks of the Meteorological Branch R.A.F.V.R. A Meteorological Section of the W.A.A.F. was opened in August 1941 and airwomen were recruited to perform Meteorological Assistant duties. A few W.A.A.F. Officers were also appointed for forecasting duties.

The total number of staff at yearly intervals throughout the war is given in the following table :—

	Officers	*Ancillary Grades*
31 March 1939	307	440
31 March 1940	616	1,080
31 March 1941	757	1,248
31 March 1942	1,051	1,905
31 March 1943	1,367	2,809
31 March 1944	1,679	3,387
31 March 1945	1,816	4,450

Policy regarding Uniform

Before the war, Meteorological Office staff was wholly civilian. During the summer of 1939, a number of officers had been commissioned in the newly formed Meteorological Branch of the Royal Air Force Volunteer Reserve and a number of airmen had been attested into the trade of meteorologist. At that time the general policy was that, in the event of war, the Meteorological Office staff would retain its civilian character while the reservists would be called up and would form the meteorological body to serve in any theatre of war where they might be required ; the few members of the old 'Meteorological Reserve' were already allocated to the European theatre and would proceed overseas with the Expeditionary Force. The policy was, therefore, clear cut : the reservists would serve in uniform in the actual theatres of operations and the Meteorological Office staff in other areas would remain civilian. In general, this remained the policy until 1942 especially as regards forecasters. It was not quite so rigid as regards subordinates. Airmen were recruited from time to time and by 1942 many of the overseas meteorological offices were staffed, as far as subordinates were concerned, almost wholly by uniformed personnel. A number of airmen were serving at home stations before the end of 1942 although civilian subordinates were also being recruited.

It had become clear by 1942 that in overseas theatres at any rate, considerations of security, mobility, accommodation, messing, etc., made the employment of civilians a source of difficulty and even of danger to the staff themselves. A new policy was, therefore, agreed, and from 1 November 1942, forecasting personnel in overseas areas, except South Africa, Canada and U.S.A., became R.A.F. Officers holding C.C. commissions. These officers were later offered commissions in the Meteorological Branch of the R.A.F.V.R.

The wearing of uniform by meteorological officers was extended to certain Home Commands on 1 April 1943, mainly because the closest possible liaison was needed between meteorological officers charged with briefing duties and the aircrews and other service personnel whom they were briefing especially for operational flights. Moreover, militarisation would facilitate posting arrangements between the United Kingdom and overseas Commands. Following the report of the Ludlow-Hewitt committee, it was agreed that in the operational home Commands all the meteorological staffs should be in uniform, as part of the Meteorological Branch of the R.A.F.V.R. The non-operational Commands retained their meteorological forecasting staffs on a civilian basis. This rule as to wearing of uniform had to be applied to movements from an Operational Command to a non-Operational Command with the result that some officers made more than one change from uniform to civilian clothes and vice versa. This extended form of the policy remained in force until the end of the war. The policy could not be rigidly applied to subordinates as the airmen and airwomen who were being recruited could not be disembodied and re-embodied according to the accident of posting. Thus, by 1943, most of the ancillary staff everywhere were in uniform. Civilian subordinates were absorbed into the R.A.F. as airmen meteorologists as they were called up for military service and at the end of the war the subordinate staff was almost wholly in uniform except at Headquarters and some of the Observatories.

Throughout the war, the establishment was always civilian although most meteorologists were in uniform by April 1943. Vacancies on the establishments overseas and in the four operational Commands at home were allowed to be filled by R.A.F. or W.A.A.F. personnel according to a scheme of equivalent ranks first promulgated in A.M.O. 529/42 which also reaffirmed the essentially civilian nature of the establishments.

Training Schools

Before the outbreak of war, the training of its personnel was a normal activity of the Meteorological Office whose Training School was located at Alfred House, Kensington. When the recruitment of officers and airmen for the newly formed Meteorological Branch of the R.A.F.V.R. was sanctioned in the early summer of 1939, the question of training the recruits demanded

[1] A.M. File 590028/36.

immediate consideration. It was laid down that instruction would be given at evening classes. A panel of volunteer instructors was readily obtained from the Meteorological Office staff, and syllabuses of instruction, for officers and other ranks were drawn up. The start of training was delayed, however, by an unsuccessful search for suitable accommodation in the London area, the policy being to open a London training centre in the first instance and later to open centres in the main provincial towns if the number of recruits warranted such a step. The first proposal was to take additional rooms at Alfred House, but this plan was dropped. Then rooms were allotted in Imperial House, Kingsway, but before arrangements had been completed, the rooms were diverted to other uses. The same fate dogged all subsequent attempts to find accommodation. As a result, war broke out with no training of reservists yet accomplished and no school available for doing it.

The whole situation changed on 3 September 1939. There was now no question of training reservists at evening schools but of instructing embodied officers and airmen in the duties of their branch or trade. The airmen reservists who reported at their Town Centre at Victory House, Kingsway, were immediately sent to R.A.F. stations all over the United Kingdom to receive their training in local meteorological offices. The officers were told to be prepared to report for training at very short notice. In a few days, rooms had been allocated at Berkeley Square House for training the Officers and Professor D. Brunt was appointed to take charge of the school. A party of about 40 officers was mobilised on 18 September 1939 and reported for training on that date. A further party of 40 reported three months later and by the end of six months, most of the officers who had volunteered in 1939 had received their school training. A few airmen were recruited during this period and they also received a course of instruction at Berkeley Square House. Concurrently with this, civilian training had been continuing at Berkeley Square House, both for forecasters and assistants. The recruitment of officers ceased after the training of these initial entrants, and the school at Berkeley Square House closed down in the summer of 1940. The training of civilian forecasters also ceased at about the same time.

The recruitment of airmen and the appointment of civilian forecasters was resumed towards the end of 1940. The training school re-opened at Barnwood, Gloucester. Meanwhile, in the early months of 1941, the extension of the trade of meteorologist to the W.A.A.F. was considered: it was agreed and the first recruits appeared for training in August 1941. Premises were secured in the Houghton House Annexe, London W.C.2. The initial rate of intake was 15 airwomen per fortnight, but this was later increased to 15 per week and still later to 30 per week. The school made a number of moves, finally settling in the vacant Orphanage of Mercy in Randolph Gardens, N.W.6. As there was considerable space in this building it was decided to bring the other school from Barnwood to London as the problem of domestic accommodation was becoming acute in the Gloucester area. This was done in August 1943, after which all training was under one roof. No further movements were made until after the end of the war.

Except for the six months during which Professor Brunt was in charge at Berkeley Square House, the whole of the forecasting training during the war, both for civilians and service personnel, was carried out under a senior technical officer of the Meteorological Office staff.

Training Syllabuses

Training of Forecasters: The duration of the courses held at the school varied from about two months at the beginning of the war to fifteen weeks towards the end of it, and corresponding variations were made in the syllabus. This extension of the course was inevitable. although the demand for forecasters continued to be urgent, for the average scientific standard of new entrants became lower, the instruction was progressively simplified and the tempo had to be reduced. On the other hand, while the area covered by meteorological observations was less than in peace-time, the steady increase in upper air information added to the complexity of the forecaster's methods. The aim of the instruction given at the School was to enable a trainee to take his place on an outstation duty roster in the shortest possible time. Nominally, his course was followed by three months' training at an outstation, but, in fact, he was often required to take full responsibility earlier. Instruction had, therefore, to be confined to basic principles at the expense of completeness, and mathematical treatment was avoided as far as possible. This was, in any case, inevitable since the average scientific standard dropped progressively from that of a university degree to little beyond matriculation.

Trainees were mostly new entrants (civilians or R.A.F. or W.A.A.F. officers) for training as dependent forecasters, but others were similar trainees who had had at least one or two years experience in the Meteorological Office on assistant work (these included N.C.O.s). Besides these two groups, there were two or three classes for independent forecaster training, but most of this work was done at Type 1 stations. The only difference in the training of the two types of dependent forecaster was that those new to meteorology started with nearly a fortnight of purely assistant work, and even less when the courses were at their shortest. All trainees then had four or five weeks in which the main work consisted of lectures on meteorological theory, and the rest of the day was spent in gaining speed in the assistant work. There were usually three lectures on each morning of a 44–48 hour working week. Towards the middle of the course, three-quarters of the theoretical work had been covered and trainees were in a position to start forecasting. The rest of the course consisted mainly of chart analysis and forecasting, using duplicated current data; every member of a class did exactly the same work but obtained his results as independently as possible. Much stress was laid on verbal forecasting and a briefing was arranged at least once a day in the later part of the course. The briefing was carried out normally, with non-technical questions, and was followed by a general meteorological discussion, which was found to be of great value to both briefer and audience. The final week or fortnight of the course was usually occupied with forecasting as nearly as possible according to station routine, using original teleprinter data and, when practicable, in conjunction with a class of assistants. Each forecaster, with one or two assistants, was then responsible for the operation of his 'station,' including written forecasts, telephone enquiries and routine observations.

The theory course started with the fundamentals of radiation, thermodynamics, condensation, etc., using as far as possible the physical and graphical approach. This was followed by a detailed study of the tephigram and its uses. The next section covered the relationship between wind and pressure, including local winds, and the basic ideas involved in forecasting high-level winds. Meanwhile, private reading on elementary synoptic work had been recommended,

so by that stage, charting was becoming more than mere plotting practice. The final lectures of this series dealt with air masses, discontinuity surfaces, depression theory and weather (stressing throughout the high-level structure and winds), and chart analysis and forecasting. The remaining lectures on anticyclones, fog, icing, thunderstorms, chemical warfare, etc., were fitted in at convenient times between the periods of practical work.

Training of Assistants : At the start of the war, an assistant only received a fortnight's very intensive training which could only serve as an introduction to facilitate the learning of the work when he reached a station. Most later courses, however, were of five or six weeks duration, although a number of W.A.A.F. courses were extended by a fortnight for training in teleprinter operation. As on the forecaster course, the period at the Training School was followed by six weeks' outstation training, after which the new entrant was normally considered fit to take full responsibility.

While a School Certificate in mathematics and physics was considered the desirable minimum qualification for an assistant, the average fell far below this and, in some later classes, half the trainees had no scientific qualifications at all. While the work involved no direct application of such knowledge, it called for speed and accuracy, alertness and keen observation ; for mental agility rather than intellectual ability.

The greatest stress was laid on good observational work and frequent observations, both in classes and individually, were made throughout the course. The next most important part of the work was chart plotting and, with the complexity of upper air data, more time was spent on plotting than any other branch of the work. The remaining items of the course were pilot ballooning (single theodolite methods, with and without tail), computation of artillery Meteor reports, and the barest essentials of meteorological theory. The theoretical work was considered the minimum necessary to give meaning and co-ordination to the practical work, and as an incentive to further reading later. As far as was allowed by the equipment available, the fullest use was made of slides and sound films. The last week of each course was planned to simulate conditions at a station and personal and telephonic enquiries were included in the routine. When practicable, the idea was carried further by combining with a small class of forecasters so as to have several complete outstation staffs.

Meteorological Air Observers

When the first three meteorological reconnaissance flights were established and equipped with Blenheim aircraft at the beginning of 1941, it was agreed that the meteorological observations would best be made by trained meteorologists. As such an observer would also have to navigate in a Blenheim, seven officers and six airmen of the Meteorological Branch of the R.A.F.V.R. were detailed to report to a navigation school for training. This scheme fell through, owing to the uncertainty of the conditions of service and the fact that the personnel involved were not volunteers, but one of the meteorologists involved in the unsuccessful scheme, who had had previous flying experience, volunteered to go on the flights as a meteorological air observer/navigator and did much to develop the observing technique and train the navigators in making meteorological observations from aircraft. He visited the various flights in succession and was finally posted to Thornaby, where crews were being trained for meteorological work, as an instructor in meteorological air observing.

Meanwhile, satisfactory conditions of service for meteorological air observers recruited from experienced Meteorological Office personnel, were being negotiated. They were finally embodied in A.M.O. A.973/42, and in September 1942, the Meteorological Air Observer Section of the G.D. Branch of the R.A.F. was formed. Aircrew status and pay were granted to the officers, but not to the N.C.O.s of the Section. This anomaly was removed shortly before the end of the war in A.M.O. A.409/45 in which meteorological air observers were awarded a flying brevet of their own.

Following the publication of A.M.O. A.973/42, volunteers from within the Meteorological Office were called for and were selected, subject to medical fitness, by officer and aircrew selection boards. At first, training consisted of three weeks at an Air Gunnery School, followed by a three-week course in navigation, and, finally, instruction in the technique of making meteorological observations from aircraft. The latter was provided at R.A.F. Station, Aldergrove, by a meteorologist whose meteorological experience had been consolidated by flying on the meteorological reconnaissance sorties from that station. Later, when larger aircraft were brought into use, and air gunners could be carried, the gunnery course was discontinued and, after the navigation course, at least eight weeks were spent at one of two meteorological Operational Training Units. This was followed by a consolidating period of about a month at one of the meteorological squadrons.

It was soon realised that meteorological air observers should be trained not only as specialists but also as members of a crew in order to promote crew-co-operation and for reasons of communal safety. Efforts were made, therefore, to allocate a meteorological air observer as a permanent member of each meteorological reconnaissance crew, but owing to early shortages of trained personnel, it was some time before this policy could be fully carried out.

The initial strength of the Meteorological Air Observer Section was ten officers and 50 sergeants, inclusive of 50 per cent backing. This strength was gradually increased until at the end of the war it stood at 28 officers and 137 N.C.O.s, including a unit of one officer and seven N.C.O.s for a special radio-meteorological flight which was formed to co-operate in investigations of the effect of meteorological conditions on the propagation of radio waves. From September 1942 to June 1945, when recruitment ceased, 34 officers and 190 airmen were trained as meteorological air observers.

Supply of Meteorological Equipment

Supply Organisation

M.O.4 continued, during the war, to be responsible for arranging for the supply of meteorological equipment. The arrangements included the co-ordination of requirements, provision and production, storage, issue and accounting. At the outbreak of war, M.O.4 was housed at South Kensington but it moved to Stonehouse in November 1939. Some stores had already been sent there in September and, with the remainder packed ready to follow at short notice, the work of supplying the rapidly increasing needs of the war-time service was especially difficult during the first three months of war. Once the evacuation had been made, however, supplies were soon sent in large quantities. The work was facilitated by the proximity of the new location to two main-line

railways, the G.W.R. to London and the L.M.S. from the south-west to the Midlands and the North. In 1941, it was found necessary to reorganise M.O.4 by creating three sections dealing with (*a*) all technical aspects, (*b*) the provision of equipment and (*c*) the storage and issue of equipment, including accounting.

Requirements of Expenditure

As far as possible, estimates of requirements of equipment for a year ahead were obtained from the operational branches of the Meteorological Office and from the Naval Meteorological Service in the latter part of each financial year The estimates were co-ordinated and passed to the Air Ministry Finance Division before taking steps to provide the necessary stocks to meet the estimated requirements. One of the major difficulties was to provide for unforeseen requirements, often arising at short notice. This difficulty increased as the war progressed, when it became necessary to supply equipment to Dominion and Allied Services and when it took longer to obtain materials.

In order to facilitate the direct purchase of equipment, the limit below which M.O.4 was empowered to place local purchase orders with firms (subject to certain financial controls) was increased early in the war from £100 to £250. Contracts above this limit were placed by the Air Ministry Contracts Directorate to whom financially approved requisitions were sent. The following figures show the annual number of contracts and local purchase orders placed during the war and during some pre-war years :—

	Yearly Average 1929–1933	*Yearly Average* 1940–1945	*Peak Year* 1942
Contracts	20	126	197
Local Purchase Orders ..	785	2,389	3,456

The increase in the total expenditure on meteorological equipment is shown by the following figures :—

Financial Year	£
1929–33 (average)	7,800
1939–40	37,000
1940–41	67,000
1941–42	86,000
1942–43	142,000
1943–44	185,000
1944–45	225,000
1945–46	212,000

The increase was due not only to the very much greater quantities of equipment required but also to the introduction of new instruments and to the increase in cost of production.

Provision of Equipment

The normal sources of supply of the ordinary meteorological instruments were some half-dozen London instrument makers, notably Messrs. Negretti and Zambra, Short and Mason, C. F. Casella, Wilson, Warden and Co., E. R. Watts

and R. W. Munro. Recording clocks were obtained from Messrs. Mercer of St. Albans and Rotherhams of Coventry. Hydrogen was obtained from the British Oxygen Co. and Messrs. Lee and Sons of Runcorn and also from the R.A.F. Depot at Cardington. As far as possible, small stores of various kinds were obtained from R.A.F. Maintenance Units.

The introduction of new types of equipment made it necessary to widen the field considerably ; moreover, when materials and production came under the control of the Ministry of Aircraft Production, close liaison had to be maintained with the Branches of that Ministry in order that suitable production facilities could be found and allocated. The risk of bomb damage to factories made it necessary to find alternative sources of supply for the more essential requirements.

The effects of bombing began to be felt towards the end of 1940 when Wilson Warden's factory, producing thermographs and hygrographs, was destroyed. Rotherham's clock factory was severely damaged in the attack on Coventry. Later, two London firms producing ferr-silicon for hydrogen generators were put out of action for a considerable time. The thermometer factory of Black and Co. was destroyed and the glass blowing shop of Messrs. Negretti and Zambra was severely damaged. Apart from the damage caused at these and other factories, a number of consignments of stores were destroyed while awaiting shipment at docks and others were lost by enemy action at sea.

The fall of France cut off for a time the supply of a few essential items such as high pressure hydrogen generators, which were made in France, and stop-watches and fusee chain (for aneroid barometers) which were made in Switzerland. The difficulty in the case of the last two items was overcome when the Ministry of Economic Warfare organised a means of obtaining supplies from Switzerland. Supplies of high pressure hydrogen generators were ultimately obtained by lease-lend arrangements from the U.S.A. after production of the French pattern had started there ; at the same time, a British design of low pressure generator was put into production in this country.

Another item obtained from the Continent at the beginning of the war was the Vaisala radio-sonde, which was made in Finland. A Meteorological Office was rapidly completed, however, and put into production by the simultaneous employment of three contractors, viz., the Union Radio Co., Tinsley and Co., and Mains Radio Co. By the end of the war, contracts for Meteorological Office radio-sondes had covered a total production of 30,000 of these instruments. Their provisioning was by no means simple, for various components and materials had first to be obtained by M.O.4 for issue on 'embodiment loan' to the contractors ; the difficulty was to ensure that every single part was available in time to maintain continuity of production. The introduction of radio methods caused a very great increase in the types of stores which had to be provisioned. For example, over 100 varieties of radio valves were required.

Other items which were required in the greatest numbers were pilot and sounding balloons of which over 2,000,000 were supplied during the war, thermometers of which 30,000 were supplied and aneroid barometers which

totalled 18,000. Certain items were continually in short supply for one reason or another: these included thermometers, aneroid barometers, recorder clocks and aircraft psychrometers.

Storage

The Stores Section of M.O.4 worked in much the same way as an R.A.F. Maintenance Unit, but on a smaller scale. All equipment bought or otherwise obtained for the meteorological services was received in this Section and stored until required for issue. The chief difficulty throughout the war was to secure enough space for the rapidly increasing quantities of equipment which had to be handled. The storage space at South Kensington before the Branch was evacuated totalled some 2,000 square feet. At Stonehouse the stores were distributed over various rooms in about six different buildings separated in some cases by half a mile or more. This dispersal was good from the point of view of bombing risk, but it added considerably to the difficulties of the Stores staff in keeping check of the stores and in assembling and packing for issue. Moreover, the accommodation could only be described as makeshift. Adequate and properly fitted store accommodation would have greatly improved the efficiency of the storage arrangements. The total amount of covered storage space available and used in the latter half of the war amounted to about 10,000 square feet. This was by no means enough and a large quantity of equipment and packing cases, occupying a further 8,500 square feet had to be kept in marquees or left in the open. A war reserve of the more essential items, which was set aside at the beginning of the war for use in case of destruction of the main stores or of breakdowns in production caused by enemy action, was housed at Cheltenham and occupied a floor space of about 1,000 square feet. This emergency store was only drawn upon on a few occasions to overcome shortages caused by delays in production.

The pressure of work and the inadequacy of the storage facilities made it impracticable to carry out stock-taking which normally is done annually. Spot checks of a few items were undertaken during the periodical visits by Air Ministry auditors and, in general, very few discrepancies were found. In fact, considering the adverse circumstances in which the stores work had to be done, losses of equipment were so small as to be negligible.

Issue of Equipment

The main responsibility of M.O.4(c) was to deal with all incoming demands for equipment and to arrange for its issue and accounting. Owing to the war-time waiver of financial adjustment for supplies made to certain Government Departments, most of the demands came under the heading of free issues but a number continued to be arranged on loan and repayment terms. The normal peace-time R.A.F. system of store accounting was continued with only minor modifications throughout the war. Briefly, this system consists in the keeping of main store ledgers in the accounting section independently of the stores section where they can be checked against the physical stocks and tally cards kept in the stores. Equipment issued to Meteorological Office stations was further accounted for by means of inventories normally checked once a year or at a change of officers in charge of a station. The large increase in the issue of equipment during the war is shown by the following annual totals of demands dealt with, including, for comparison, average figures for some

pre-war years. (It should be mentioned that most demands during the war covered numerous items and, in general, considerably more than in normal times) :—

Year	*No. of Demands*
1929–33 (average)	2,775
1939	5,940
1940	6,652
1941	8,355
1942	9,931
1943	11,103
1944	12,470
1945	9,356

Thus, the peak was reached in 1944, the largest numbers in any month being 1,341 in April of that year, when preparations for D Day were at their height.

About 260 new meteorological offices at R.A.F. stations in the United Kingdom were supplied with complete equipment during the war. In addition, Supplies for the 80 or so permanent stations were maintained. Wind indicating instruments and other equipment were issued to Flying Control Offices at 83 R.A.F. airfields and 28 meteorological units at Balloon Command stations were so supplied. At the beginning of the war two very large consignments of stores were ready for shipment to the meteorological sections of the B.E.F. and in the months preceding D Day large quantities of equipment were issued to the sections in 2nd T.A.F. A very important part of supply work which grew rapidly during the war was the issue of meteorological equipment for aircraft of the Meteorological Flights and of radio equipment to the radio-sonde and radio-wind stations.

Overseas, the meteorological stores depot in Middle East was expanded to five times its original holding and the other main pre-war stores at Aden, Iraq, Malta and Gibraltar were greatly increased. With the taking over by the Meteorological Office of the Colonial Services in East and West Africa, the equipment in those areas was maintained and considerable quantities of new instruments supplied. Nine sets of instruments were sent to the North Africa Expeditionary Forces and these sets were later expanded to form a store depot for the whole of M.A.A.F. Command. Later in the war, supplies were sent to India for the equipping of meteorological sections in S.E.A.C.

In addition to this work of supplying units under Meteorological Office control, a very large proportion of time was taken up in supplying other users. The needs of the Naval Meteorological Service were met by regular issues of very large quantities of equipment to the R.N. Dockyards. Nearly 100 Weather Offices of the U.S.A.A.F., who were short of American equipment when they first arrived in the United Kingdom, were supplied with a large number of British instruments under lease-lend arrangements. Dominions and Colonial Meteorological Services who had before the war bought some or all of their instruments direct from firms in the United Kingdom found difficulty in continuing this practice owing to Government control of production. Arrangements were made for the Instruments Branch to act as their agents and to supply from M.O.4 stocks as far as possible. Many of the Allied Meteorological Services, finding their normal sources of supply cut off, asked for help in

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equipping their stations and arrangements were made to issue supplies to the Fighting French, Belgians, Greeks, Dutch and Norwegians for use in such areas as French West Africa, French Sudan, Reunion, Syria, Jan Mayen and the Belgian Congo. Some equipment, notably radio-sonde balloons, was also sent to the U.S.S.R. More often than not, little warning of such requirements was received, but it was usually possible to meet them without much delay.

Forms and Books

Despite the very considerable increase in the requirements which arose from war conditions, the administrative machinery which was in operation before the war for the printing and distribution of official publications, forms and charts, and the provision of non-official books for purposes of training, study and reference, continued to perform these functions throughout the war without material change other than necessary expansion.

In addition to providing for the requirements of the British meteorological units with the R.A.F. and the Army in the various theatres of war, and of the voluntary co-operating climatological and rainfall stations in the United Kingdom, considerable quantities of forms and M.O. publications were provided for the Naval Meteorological Service and about 100 units of the U.S.A.A.F., as well as for other Allied Forces.

The development of the various phases of the war and its extension to other parts of the world necessitated the production, from time to time, of new charts and forms and by August 1945, 115 such items had been introduced. Many of these were outline charts for the plotting of synoptic information for new areas, several were sectional charts for the use and information of captains of aircraft in flight, while others were designed to meet advances in the technique of upper air observation and analysis.

Losses of machinery, paper and printed stocks, caused by aerial bombardment, particularly of the London area, resulted in acute difficulty in the maintenance of supplies. This position was met partly by diverting to the Admiralty Press at Taunton a certain amount of the lithographic printing, by printing supplies of certain items in Canada and by the use of a facsimile typewritten method of reproduction, instead of letterpress, for a considerable number of the war-time publications. The production of certain items in Canada was of particular benefit to meteorological units operating in that country as it not only expedited the process, but removed the risk of loss formerly involved in course of transit by sea across the Atlantic.

APPENDIX No. 1

EMERGENCY ORGANISATION FOR THE SUPPLY OF WEATHER REPORTS AND FORECASTS TO THE FIGHTING SERVICES. DISTRIBUTION OF METEOROLOGICAL STAFF PROPOSED BY METEOROLOGICAL OFFICE TO FULFIL RECOMMENDATIONS OF MEETNG HELD 19 SEPTEMBER 1938

1. In accordance with para. 4 of the minutes of a meeting held in Room 641 on 12 September 1938 to discuss emergency distribution of M.O. staff, it is understood that the immediate requirements are as follows ; and that these are additional to the personnel of the R.A.F. Meteorological Reserve required to accompany the A.A.S.F.

(i) The maintenance of a central forecast and information bureau at a headquarters in or near London.

(ii) The provision of meteorological stations on continuous duty as follows :—

Priority 1	*Type of Station*
Bomber Command H.Q.	1
Coastal Command H.Q.	1
No. 1(B) Group H.Q.	1
No. 2(B) Group H.Q.	1
No. 3(B) Group H.Q.	1
No. 4(B) Group H.Q.	1
No. 5(B) Group H.Q.	1
No. 12(F) Group H.Q.	1
Fighter Command H.Q.	1

Priority 2	*Bomber and G.R. War Stations* *Type of Station*
Bicester	3
Bassingbourn	3
Cranfield	3
Upper Heyford	3
Feltwell	3
Honington	3
Marham	3
Stradishall	3
Dishforth	3
Driffield	3
Finningley	3
Manston	1
Hemswell	3
Eastchurch	3
Waddington	3
Cottesmore	3
Warmwell	3
Mount Batten	2
Invergordon	2
Tayport and Leuchars	2+
Montrose	3
Bircham Newton	3
Thornaby	3

2. **Notes on 1 (ii)** :—

(*a*) No. 11 (F) Group has been omitted because it is now situated at Bomber Command Headquarters. So long as that situation lasts the one Meteorological Station should serve both H.Q.

(*b*) No. 16 (R) Group H.Q. has been similarly omitted because of its present proximity to Coastal Command H.Q.

(*c*) The Meteorological Stations allocated to Watton and Cottesmore Aerodrome have been omitted because the aerodromes are not ready.

(*d*) Staff has not been allotted to Wyton, Mildenhall and Linton-upon-Ouse Aerodromes because Type 1 Stations are provided at the neighbouring Bomber Group H.Q.

(*e*) Owing to staff shortage, a Type 1 Station would not initially have its full peace time complement, but would be manned by one Senior Technical Officer, three forecasting Officers and four Assistants III.

(*f*) Each Type 2 station would be augmented to permit of working continuously. Initially it would be manned by two Forecasting Officers, one Assistant II and three Assistants III or observers.

(*g*) Each Type 3 station would also be augmented to enable it to work continuously. Initially, it would be manned by two Assistants II and three Assistants III.

(*h*) Tayport and Leuchars are so close together that a station styled "Type 2 + " has been allotted to serve both. The initial complement would be two Forecasting Officers, two Assistants II and four Assistants III or Observers.

(*j*) Mount Batten and Invergordon have been allotted Type 2 stations since they are required also by the Navy. (*See* para. 3 below.)

3. Additional Naval Requirements

Continuous duty forecasting stations are required at :—

	Type of Station
Mount Batten	Already provided
Invergordon	Already provided
Portsmouth..	Served by Coastal H.Q.
Sheerness or Chatham	X
Rosyth	X
Main base of the Home Fleet	1

4. Notes on Paragraph 3

(*a*) The requirements at Portsmouth are satisfactorily met from Coastal Command H.Q. so long as those H.Q. remain at Lee-on-Solent.

(*b*) The stations at Sheerness or Chatham, and that at Rosyth would each be manned as follows :—one Assistant II, one Naval Met. Officer (Retd.) and two Assistants III. Teleprinter lines are already installed to Chatham and to Donibristle, where the Meteorological Staff would work.

(*c*) If the main base of the Home Fleet is at Scapa Flow, a Type 1 station should be provided there, and consideration given to the method of communications.

5. Requirements of Training Command

Provision has been made for the instructional work in Meteorology to be continued at the School of Air Navigation and the School of General Reconnaissance. It has been assumed that no meteorological personnel will be required at any other Training Stations.

6. The above requirements can, it is considered, be met now by the Meteorological Office.

APPENDIX No. 2

HOME WAR STATIONS OF THE R.A.F.—IMMEDIATE METEOROLOGICAL REQUIREMENTS

War Time Meteorological Offices

Type 1.	24 hours full forecasting.
Type 2.	24 hours, but reduced establishment.
Type 2(a).	Limited forecasting service.
Type 2(c).	Limited forecasting service with lecturing.
Type 3.	24 hours subsidiary forecasting and reporting.
Type 3(a).	16 hours subsidiary forecasting and reporting.
Type 4.	24 hours interpreter and reporting.
Type 4(a).	16 hours interpreter and reporting.

Station	Type	Remarks
Bomber Command		
1. Operational Stations		
Command Headquarters	1	
No. 2 Group H.Q., Huntingdon ..	1	
No. 3 Group H.Q., Mildenhall ..	1	
No. 4 Group H.Q., York	1	
No. 5 Group H.Q., Grantham ..	1	
No. 6 Group H.Q., Norwich ..	2	
Bicester	3 (a)	
Wyton	3	
Bassingbourn	3	
Cranfield	3	
Feltwell	3	
Honington	3	
Marham	3	
Mildenhall	3	
Stradishall	3	
Dishforth	3	
Driffield	3	
Linton	3	
Hemswell	3	
Scampton	3	
Waddington	3	
Watton	3	
Wattisham	3	
West Raynham	3	
Benson	3 (a)	
2. Non-Operational Stations		
Abingdon	3 (a)	No. 6 Group to Abingdon.
Norwich	3 (a)	
Boscombe Down	3 (a)	
Harwell	3 (a)	
Cottesmore	3 (a)	
Upwood	3 (a)	
Leconfield	3 (a)	
Finningley	4	
Upper Heyford	3 (a)	
Balloon Barrage		
Balloon Command H.Q.	1 Meteorologist	

Station	Type	Remarks
Coastal Command		
1. Operational Stations		
Command Headquarters	1	
No. 15 (R) Group H.Q., Plymouth..	1	
No. 16 (R) Group H.Q., Chatham ..	1	
No. 18 (R) Group H.Q., Rosyth	1	
Mount Batten	3	
Warmwell	2	
Thorney Island	2	
Detling	3	
Bircham Newton	2	
Catfoss	2	After July 1939.
Thornaby	2	
Leuchars	2	
Montrose	2	
Invergordon	2	
Lerwick	2	
Aldergrove	2	
2. Non-Operational Stations		
Calshot	4	
Felixstowe	4	Reporting.
Abbotsinch	2 special	
Fighter Command		
1. Operational Stations		
Command Headquarters	1	
No. 11 (F) Group H.Q., Uxbridge..	1	
No. 12 (F) Group H.Q., Hucknall ..	1	
No. 13 (F) Group H.Q., Newcastle..	1	
Tangmere	4	
Croydon	4	
Biggin Hill	4	
Kenley	4	
Hornchurch	4	
North Weald	4	
Northolt	4	
Filton	4	
Debden	4	
Duxford	4	
Wittering	4	
Digby	4	
Hucknall	4	
Church Fenton	4	
Catterick	4	
Usworth	4	
Turnhouse	4	
Andover	3	
S. Farnborough	2	

Station	Type	Remarks
Training Command		
Non-Operational Stations		
Evanton	2 (c)	
West Freugh	2 (c)	
Cranwell	4	
Penrhos	2 (c)	
Thorney Island	Lecturer	Already provided.
Manston	4	
Eastchurch	4	
Manby	4	
Netheravon	4	
Brize Norton..	4 (a)	
South Cerney	2 (a)	
Sealand	4	
Little Rissington	4	
Peterborough	4 (a)	
Hullavington..	4	
Ternhill	4 (a)	
Shawbury	4 (a)	
Grantham	4 (a)	
Gullane	4	
Kinloss	4 (a)	
Lossiemouth	4	
Jurby	2 (c)	
Pembrey	2 (c)	
Porthcawl	2 (c)	
Aldergrove	}	Already provided
Warmwell	}	Already provided
Montrose	}	Already provided

Home War Stations of the R.A.F.—Eventual Meteorological Requirements

War Time Meteorological Offices

Type 1.	24 hours full forecasting.
Type 2.	24 hours, but reduced establishment.
Type 2(a).	Limited forecasting service.
Type 2(c).	Limited forecasting service with lecturing.
Type 3.	24 hours subsidiary forecasting and reporting.
Type 3(a).	16 hours interpreter and reporting.
Type 4.	24 hours interpreter and reporting.
Type 4(a).	16 hours interpreter and reporting.

N.B.—These requirements are based on the latest Scheme 'M' list of Command Headquarters, Groups and Operational and Non-Operational Stations.

Station	Type	Remarks
Bomber Command		
(a) Command Headquarters		
Upper North Dean	1	
Bomber Groups		
Abingdon (No. 1 Group)	1	Manned by A.A.S.F. Section until Group goes to France.
Huntingdon (No. 2 Group) ..	1	
Mildenhall (No. 3 Group)	1	
York (No. 4 Group)	1	
Grantham (No. 5 Group) ..	1	
Norwich (No. 6 Group)	1	
Stations		
Group 1		
Abingdon	3 (a)	Type 3 meteorological offices will be required at these stations, until squadrons go overseas, when their function will become Group Pools etc. Extra personnel to be found from A.A.S.F. Meteorological Sections.
Benson	3 (a)	
Bicester	3 (a)	
Boscombe Down	3 (a)	
Harwell	3 (a)	
Middle Wallop	3 (a)	
Upper Heyford	3 (a)	
Group No. 2		
Bassingbourn	3	
Bramcote	3	
Cottesmore	3	
Cranfield	3	
Upwood	3	
Wyton	3	
Group No. 3		
Feltwell	3	
Honington	3	
Marham	3	
Mildenhall	3	
Stradishall	3	
Group No. 4		
Dishforth	3	
Driffield	3	
Hatfield Woodhouse	3	
Leconfield	3	
Leeming	3	
Linton-upon-Ouse	3	
Topcliffe	3	
Group No. 5		
Binbrook	3	
Finningley	3	
Grantham	3	
Hemswell	3	
Newton	3	
Scampton	3	
Waddington	3	

Station	Type	Remarks
Bomber Command—*contd.*		
(a) Command Headquarters—*contd.*		
Group No. 6		
Coltishall	3	
Horsham St. Faith	3	
Wattisham	3	
Watton	3	
West Raynham	3	
Manston	4 reporting	If used by No. 1 Group aircraft for operations additional staff of A.A.S.F. meteorological section can be made available either at home stations or at these advanced bases as required until squadrons go overseas.
Martlesham	4 } if	
Eastchurch	4 } required	
(b) Fighter Command		
Command Headquarters		
Stanmore ..	1	
Group Headquarters		
Hucknall (No. 12 Group) ..	1	
Newcastle (No. 13 Group) ..	1	
Uxbridge (No. 11 Group) ..	1	
Fighter Stations		
Debden	4	
Hornchurch	4	
Kirton-in-Lindsey	4	
Biggin Hill	4	
Croydon	4	
Church Fenton	4	
Digby	4	
Duxford	4	
Kenley	4	
West Malling	4	
North Weald	4	
Tangmere	4	
Turnhouse	4	
Wittering	4	
Ouston	4	
Swanton Morley	4	
Colerne	4	
Catterick	4	
Hucknall	4	
Northolt	4	
Usworth	4	
Hendon (Communication Squadron)	4	Reporting only.
Farnborough (Army Co-operation)	2	Form R.A.E. and reporting.
Odiham (Army Co-operation) ..	—	
Abbotsinch (Army Co-operation)	—	
Andover (Army Co-operation) ..	—	
Hawkinge (Army Co-operation) ..	—	
Old Sarum (Army Co-operation) ..	—	

Station	Type	Remarks
(c) Coastal Command		
Command Headquarters		
London ..	1	
Group Headquarters		
Chatham (No. 16 Group) ..	1	
Rosyth (No. 18 Group)	1	
Plymouth (No. 15 Group) ..	1	
Stations		
Bircham Newton	2	
Detling	3	Close to 16 Group.
Leuchars	2	
Pembroke Dock	2	
Thorney Island	2	G.R. squadron and School of G.R.
Wick	2	
Aberdeen	2	
Aldergrove	2	
Mount Batten	3	Close to 15 Group.
Newquay	2	
Thornaby	2	
Catfoss	2	
Gosport	—	Training.
Calshot	4	Flying-Boat Training.

(d) Training Command

Final lay-out of Training Command has not yet been decided, but below is a list of 14 Service Flying Training Schools approved under Scheme 'L'.

Station	Type	Remarks
Brize Norton	4 (a)	
Little Rissington	4	Reporting.
Gullane	4	Reporting.
Hullavington	4 (a)	
Kinloss	4 (a)	
Lossiemouth	4	Reporting.
Montrose	4	Reporting.
Netheravon	4 (a)	
Peterborough	4 (a)	
Sealand or replacement	4	Reporting.
Shawbury	4 (a)	
South Cerney	2 (a)	Forecasting and reporting.
Ternhill	4	
Cranwell	4	
Replacement for Grantham	4	
Two additional unselected	4 × 2	
Observer Schools		
Jurby	2 (c)	
Pembrey	2 (c)	
Aldergrove	2 (c)	
West Freugh	2 (c)	
Penrhos	2 (c)	
Warmwell	2 (c)	
Porthcawl	2 (c)	
Evanton	2 (c)	
Five additional unselected ..	2 (c) × 5	

Station	Type	Remarks
Air Navigation Schools		
Two unselected	1 special × 2	
Air Armament Schools		
Manby	2 (a)	
Eastchurch *or*	4	
Pembrey	2 (a)	
Central Flying School		
Upavon	—	

(e) Additional War Training Requirements, Scheme 'M'

The foregoing lists do not include additional training units which will be formed in War. The locations of these are still under discussion, but the numbers foreseen will be as follows.

	Total Number required in War	Assumed available in Peace and War	Additional to be formed in War	Type of Met. Offices required
Service F.T.S.	35	17	18	4(a) × 18
Air Observers Schools	24	13	11	2(c) × 11
Schools (G.R.)	6	1	5	2(c) × 5
Torpedo Training Schools ..	3	1	2	4 × 2
Flying Instructor Schools ..	2 or 3	1	1 or 1	Nil

(f) Balloon Command 1 meteorologist

Headquarters

APPENDIX No. 3

ADMIRALTY PROPOSALS TO AIR MINISTRY REGARDING THE METEOROLOGICAL WAR ORGANISATION, 25 OCTOBER 1935

(*a*) In the vicinity of the war area all issues of meteorological data by wireless in clear should cease, and the publication of meteorological information in the Press or the supply of it to the public should be suppressed.

(*b*) Fleet Synoptic Messages and other wireless transmissions of meteorological data which it was necessary to continue should be encyphered, and a special meteorological cypher should be prepared for use by all shore meteorological services in the British Commonwealth and by H.M. Ships.

(*c*) At least two Fleet Synoptic Messages per day would be required from each meteorological centre, each message consisting of surface reports, upper wind and upper air temperature data from as many stations as might be possible or desirable, special ship reports, general inferences, forecasts and storm warnings.

(*d*) A 24-hour forecasting service should be maintained at each meteorological centre in the British Commonwealth liable to be called upon to issue forecasts for the Fleet.

(*e*) Arrangements should be made for obtaining confidentially, possibly through the Air Attachés, meteorological data from potentially allied countries or neutral countries under British influence.

(*f*) The quarterly charts of meteorological conditions over the oceans which were being prepared in the Marine Division of the Meteorological Office were inadequate, and should be replaced by monthly charts which would also indicate percentage frequencies of visibilities, cloud types and cloud amounts in addition to the data already shown.

(*g*) Reports on the vulnerability of naval bases to attack by chemical methods should be prepared and issued as confidential appendices to the handbooks on local meteorology which were being prepared for naval use in the Meteorological Office.

(*h*) Meteorological forecasting centres should be established in peace at Aden and Gibraltar.

(*i*) An inter-service and inter-departmental conference should be convened to co-ordinate the war requirements of the services.

(*j*) The shore meteorological services of the British Commonwealth should be informed of the co-ordinated war requirements of the services and requested to co-operate in establishing the necessary organisation.

APPENDIX No. 5

TACTICAL USE OF WEATHER FOR BOMBER OPERATIONS

Attack on Milan, 24 October 1942

Many important operations by a single Group, such as the attacks on Le Creusot and Genoa in October 1942, and later the Möhne Dam, Friedrichshafen and Tirpitz raids, were carried out when it was forecast that the weather conditions would be as tactically required. As an example, the planning of the sunset raid on Milan on 24 October 1942 by Lancaster aircraft of No. 5 Group may be taken as typical.

Early in September 1942 the A.O.C. No. 5 Group told his Air Staff and his Senior Meteorological Officer at a secret conference that the C.-in-C. had ordered him to carry out a sunset raid on Milan as soon as re-equipment of the squadrons had reached 70 Lancaster aircraft and the weather conditions were favourable.

What weather conditions could be looked upon as favourable were discussed by Air Staff and ultimately were visualised in detail as follows :—

Bases for take-off in the forenoon—fit.

Abingdon—for rendezvous of aircraft—cloud base above 1,500 feet with good visibility beneath the cloud.

Over the English Channel—for the gaggle to fly at sea-level and so not alarm enemy radar and fighters—surface visibility beyond 5 miles.

French coast—to keep enemy fighters grounded—very low cloud, bad visibility, rainstorms.

Loire area between Angers and Tours—to enable gaggle to re-form—cloud base 3,000 feet and good visibility below.

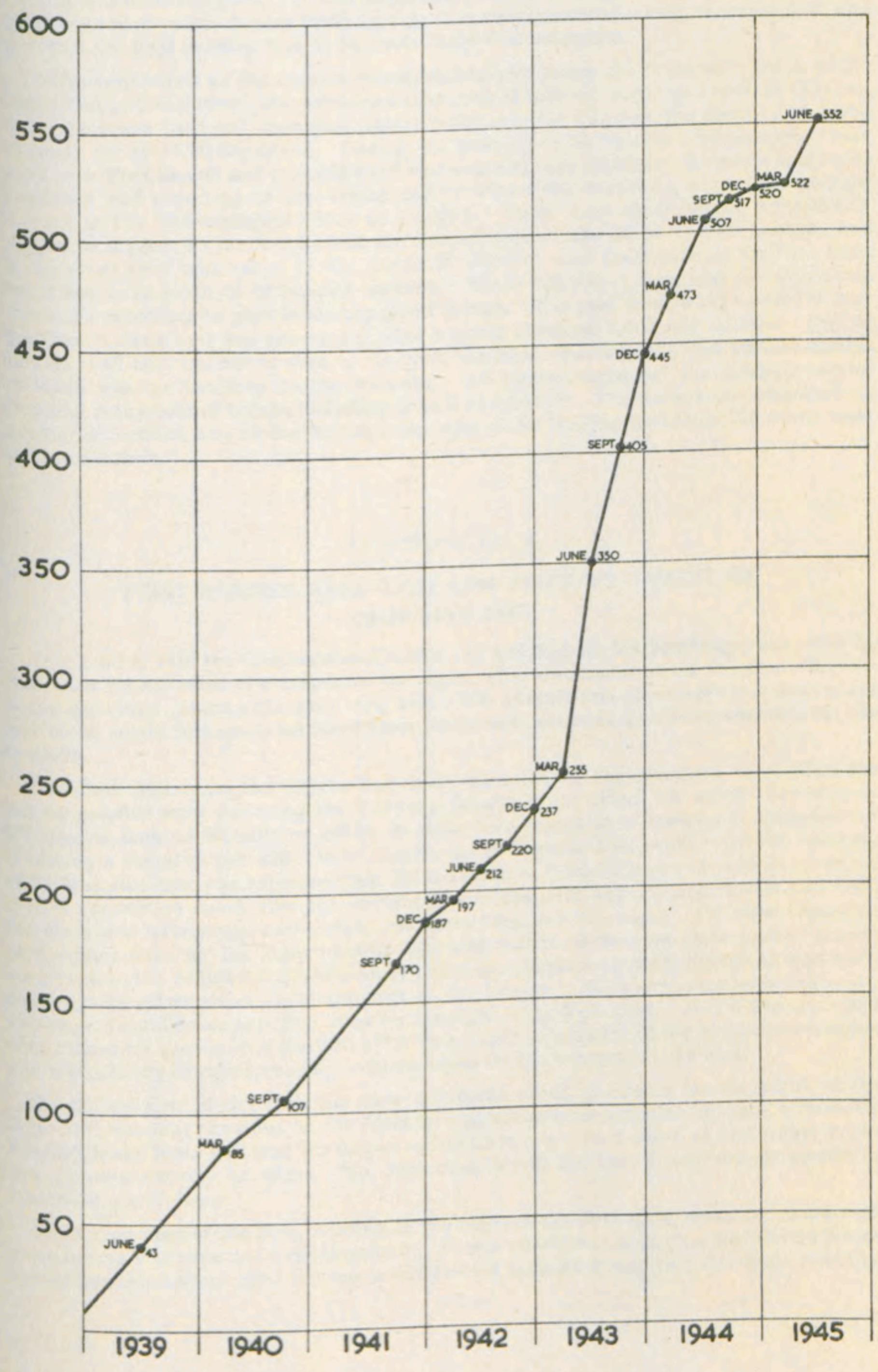
Thence to Alps and Milan—to enable gaggle to keep in visual touch, cross Alps safely and see target—no thick low cloud and good visibility below.

Milan to bases—favourable conditions to avoid wasting time and therefore petrol which would be running short. In particular bases on the south coast of England (Tangmere, Ford, Thorney Island, also Manston) to be guaranteed for any necessary weather or petrol diversion.

The A.O.C. asked whether the S.Met.O could imagine a weather map on which these conditions would all be fulfilled, and was told that the ideal seemed to be a map showing a cold front of narrow proportions situated east–west along the French coast after it had passed southwards across Great Britain, with northerly winds to its north side and westerly wind to the South. Time of take-off and in particular time over north France would depend on the winds to the target, which had to be reached 15 minutes before sunset. It would therefore be as well to arrange three routes from Abingdon to the Loire, say via Brest area (A), via Cherbourg area (B) and via Le Havre area (C), so that when the operation was put on, the crews could be briefed to take route A or B or C, according to the forecast position, at the essential time, of the cold front over the southern Channel.

APPENDIX 4

NUMBER OF RECIPIENTS OF FIRST CHANNEL TELEPRINTER BROADCAST FROM E.T.A.



The S.Met.O. was duly informed when the aircraft were available (about 15 October) and asked to watch for his ideal weather conditions, giving 36 hours' warning so that aircrew were not sent night-bombing during the night preceding this operation.

During the period 20–22 October a cold-front some 50 miles wide progressed slowly southwards over Great Britain, became stationary for a while over the Midlands and then on the morning of 23 October showed signs of moving very slowly southwards. The 36 hours warning was therefore given. It was important that stations should not be warned nor the aircrews briefed unless it were fairly certain that the operations would be attempted, and therefore the final decision had to be made early that afternoon.

Preliminary winds at the various operational heights along the route were given to the Group Navigation Officer, who calculated that time of take-off would be 11.30, 24 October. Everything was 'laid on', including fighter cover over the Channel, the crews briefed and all ready for an 11.30 departure. During the morning of 24 October Pampa sorties were flown over the Channel and the cold-front was watched very carefully, the pilots landing at Tangmere and reporting to the Watch Officer where the telephone was ready plugged through to the Meteorological Office at 5 Group. From these observations the S.Met.O. was led to suggest to the A.O.C. that the aircraft should take off at 11.00 if possible, and in the event they took off at 11.10. These 20 minutes were invaluable as the cold front was a few miles south of its forecast position. Route (B) was chosen, and the whole raid proceeded according to plan in all important details. The cold front was in position over the French coast and was penetrated after a quick climb at 7,000 feet without icing, or fighters: all the rendezvous were as required, the Alps, clear and the thin strato-cumulus at Milan was no handicap to the bombing. All aircraft attacked the primary target, dropping many tons of bombs including several of 4,000 lb. The route home presented no weather difficulties, and all the British bases were fit for landing, including the south coast and Lincolnshire.

APPENDIX No. 6

FIRST BOMBER RAID WITH 1,000 AIRCRAFT—NIGHT OF 30–31 MAY 1942

As a general rule the Commander-in-Chief did not divulge his bombing plans until he had made his selection of a target for the night, after discussion of the weather situation in the morning. The first bomber raid with 1,000 aircraft was an exception in that plans had to be made further in advance than usual and forces had to be conserved for the occasion.

The Chief Meteorological Officer had been informed of the intention to employ the largest possible force including the Training Groups in an attack on either Hamburg or Cologne as soon as weather at either of these two places gave reasonable prospects of obtaining a visual target with 'safe' conditions at bases and on route. On the morning of 29 May the view was expressed that for the night of 29th–30th the adverse factor was a belt of convection cloud over the western North Sea with tops to high levels and both targets would have much convection cloud persisting into the night: the view expressed at the same time for the night of 30th–31st was that conditions on route and at targets were expected to be less cloudy with fewer high-topped clouds on route though an assurance could not be given about cloud amounts at the targets. No discrimination between the two targets could be made at that stage for the night of the 30th–31st. Doubt was expressed about bases for the night of the 30th–31st on account of a threat of fog patches developing and a possibility of rain spreading to home bases by the morning of the 31st.

On the evening of the 29th the view expressed about prospects for the night of the 30th–31st was that the front on the Atlantic was not now expected to advance sufficiently to affect home bases and that the targets would have convection cloud at first which might not disperse entirely at night. No distinction could be drawn between prospects at Hamburg and Cologne.

On the morning of the 30th, relating to the night of the 30th–31st, thundery cloud with some breaks was expected over Hamburg. It was considered that over the Middle Rhine convection cloud would tend to clear but it was not possible to say that clearance would be

definitely less than $\frac{5}{10}$th. At bases local showers of a thundery type were expected at first but convection cloud would decrease : the great majority of bases were expected to remain fit, only a few being affected by ground fog. At the same time the prospects for the night of the 31st May to 1st June were given as target areas having a better chance of little cloud, but there existed the possibility of rain and low cloud spreading to bases from the south-west.

It is perhaps of interest to reproduce from the ' Enquiry Book ' the record of the advice given to the Commander-in-Chief at 1700 hours on the 30th : this summary had been agreed with the Groups :—

> ' Discussed 1300 chart : take-off good at almost all stations, might be local interference owing to thunderstorms. Route to Cologne—plenty of cloud on way out, possibly odd thunderstorms with solid cloud to 25,000 feet : probably mostly in layers and residual cumulus. No definite limit to highest cloud. Cologne—broken cloud, some good breaks. Amount $\frac{1}{2}$ to $\frac{7}{10}$ths covered, which means $\frac{10}{10}$ths sometimes and may be less than $\frac{3}{10}$ths at other times, $\frac{1}{2}$ to $\frac{3}{4}$ is most probable. Return—rather better cloud conditions. Bases reasonably good apart from local visibility trouble, definitely local affecting only a small proportion of stations. Nos. 1 and 5 Groups more likely to have visibility troubles than others but in these Groups not more than 25 per cent of stations expected to be ' red ' at dawn. For bases as a whole percentage of stations ' red ' expected to be considerably less than 25 per cent.'

A ' Pampa ' was sent out which reported back around 2130 hours. At 2140 a final survey of the weather situation was given to the effect that, as a result of the ' Pampa ' sortie, the convection cloud would have lower tops than had previously been described and that over the target there were many patches of residual convection cloud. As regards bases there was no change in the forecast made at 1700 hours.

At 2300 hours the advice given to Central Flying Control for returning aircraft was that the position in the West was not clear, but it was considered that only stations on the south coast would be affected. Elsewhere over the country the gradient was opening out and by dawn there would be a very light wind or calm over most of the country. Visibility, as shown on the hourly chart for 2200 hours D.B.S.T., was good and in view of the fact that such medium cloud was reported fog was considered unlikely. The only threat to home bases would be on airfields near the larger industrial areas towards dawn and it was emphasised that these would be few in number, mainly in the N. Midlands area. Local deterioration (temporary) would be expected during the night due to showers.

Advice was given to Central Flying Control afterwards at 2345, 0100, 0200, 0240, 0440 and at 0545 hours. At no time did it differ appreciably from that given at 2300 hours.

The summary of weather prepared after the event, based on reports from aircrew and surface reports, reads as follows :—

Target—Cologne

Cloudless apart from varying amounts of cirrus. Reports of cloud to SW., SE. and NE. of target.

Visibility good.

Route

Winds 7,000 feet	270°	25 m.p.h.
12–14,000 feet	270°	30–35 m.p.h.

Visibility good.

Cloud $\frac{8}{10}$–$\frac{10}{10}$th over North Sea in layers generally from 4–6,000 feet and 8–10,000 feet, but cumulo-nimbus at times extending from 4,000 feet–15,000 feet with considerable static and heavy clear ice in cloud. Patches of fog on surface. Cloud amount in extreme southern North Sea more of order $\frac{5}{10}$th tops 6–8,000 feet.

Cloud breaking inland over Holland to nil.

Bases

Mainly ' green ' all night. Showers at first in Midlands and 3 Group area with local thunderstorms, local outbreaks of rain later in No. 2 Group, Midlands and in No. 4 Group but not widespread and base of cloud not below 1,000 feet. Visibility generally moderate but 2,000 to 4,000 yards towards dawn in Nos. 1 and 5 Group areas.

APPENDIX No. 7

SYLLABUS OF METEOROLOGICAL TRAINING FOR PILOTS AND OBSERVERS (FORM 2448)

INTRODUCTION

1. Object of Teaching :
   (i) To introduce aircrews to the medium in which they will operate.
   (ii) To enable them to discuss weather information with meteorological staffs and to bring back flight reports that will be of value to others.

2. Note on Weather Observation.—From the earliest stages students must be taught to look at the weather, and encouraged to do so by hints at the end of each lecture.

3. Training Stages.

Stages A and B
- Pre-entry aircrew candidates.
- Air Training Corps.
- Short University Courses.
- Reception and Initial Training Wings.
- Air Crew Wing (AG/WO).
- University Air Squadrons.

Stage C
- Elementary Flying Training Schools.

Stages C and D
- Elementary Air Navigator Schools.

Stage D
- Service Flying Training Schools.

Note.—Until the following syllabus has been brought into general use for new entrants, stages A, B and C will be done at the E.A.N.S. and stage D at the A.O.S.

4. Meteorological Handbook for Pilots and Observers.—A handbook has been prepared according to the following syllabus.

Syllabus

Stage A

Introduction. Growing importance of meteorology. Reasons why aircrews should study it. Personal weather observations. Co-operation with meteorological staffs.

1. Atmosphere, pressure, temperature. Composition of the atmosphere. Nature of air pressure ; measurement by mercury and aneroid barometer. The Mk. XIII aircraft altimeter. Vertical and horizontal pressure changes. Vertical and horizontal temperature changes. The five temperature zones.

2. *Wind—wind velocity.*—Terminology for surface and upper winds. Wind changes with height. Value of accurate wind estimation in navigation. Gustiness and bumpiness, particularly near surface. Effects on flying.

3. *Cloud and fog.*—Cooling of rising air. Dew point. Water-drop and ice-crystal clouds. How rising air currents may be set up. Heap and layer clouds ; examples of formation and associated weather. Fog in relation to flying. Fog formation by night cooling over land and air movement at sea. Fog thickness variations.

4. *Weather—rain formation.* Light and heavy rain. Formation and nature of snow, sleet and hail. Thunder and lightning ; cloud types and weather associated with thunderstorms. Flying conditions, and precautions to be taken in thunderstorms. Glazed frost ; favourable conditions for ice formation on aircraft.

Stage B

5. *Clouds.*—Reason for using technical terms in meteorology. Importance of knowledge of cloud types and associated weather. The ten fundamental cloud types. Meaning of prefixes and cloud names. Cloud heights. Set of cloud photographs and notes from

'Cloud Atlas for Aviators'. Aircraft forming their own cloud (condensation trails). Cloud reporting; amount and base height. Cloud observation; balloon and cloud searchlight observation, comparing with high ground, and observing from aircraft. Judging cloud height by eye. Estimating cloud thickness.

6. *Visibility*.—Definition. Measuring visibility by day. Visibility scale; 27 yards to 31 miles. Measuring visibility at night.

7. *Wind*.—Veering and backing. Measuring surface wind velocity by instruments and by eye. The Beaufort scale. Measuring upper wind velocity by pilot balloons and cloud observation.

8. *Pressure, temperature, humidity*.—Pressure readings; why the millibar unit is used. Average mean sea level millibar pressure in British Isles, and average pressure decrease with height. Use of horizontal pressure variation to forecast wind velocity. Corrections applied to obtain M.S.L. value of pressure. Use of mercury barometer by duty pilots. Measurement of temperature on ground and in aircraft. Aircraft thermometer lag. Relative humidity; saturated air; dew point. The wet and dry-bulb thermometer, use in forecasting.

9. *Altimeters*.—Example of effects of change of pressure along a flight track; effects of changes of pressure on altimeter readings, and some rules to remember. Need for a sensitive altimeter. The Kolsman sensitive or Mark XIV altimeter described. Setting and reading the altimeter. Temperature allowances.

10. *Air density*.—Variation with height and temperature changes. Effects of reduced air pressure on lift, airscrew thrust, airspeed indicators, engine power, and take-off and landing run.

11. *Introduction to the weather map*.—The Beaufort weather notation. Wind force. How weather maps are constructed. Information entered on weather maps; a simple map. Isobars; meaning, how drawn, how they change. Wind force and isobars. Buys Ballot's law.

Stage C

12. *R.A.F. Meteorological Service*.—The four types of meteorological offices. The work of meteorological officers.

13. *Flight weather reports and forecasts*.—Report and forecast defined; vital need to appreciate the difference. Obtaining forecasts for flights in Great Britain and for flights territorial waters. Standard information given in forecasts. Example of a Form 2330; how used. Co-operation between aircrews and the Meteorological Service.

14. *Routine* weather forecasts and warnings. Local routine forecasts. Warnings of impending gales, squalls and thunderstorms, and frost.

15. *The basis of forecasting*.—Study of behaviour of air masses and fronts. Weather associated with typical air masses and fronts. Climates and seasons; typical weather in different parts of world. Influence of latitude, time of year, and presence of large land or sea areas.

16. *Meteorological codes*.—Purpose and uses of standard code. Secrecy in war. Symbolic form of weather reports. Use of Form 2331. Examples showing results of careless reporting by a duty pilot. Plotting and interpreting the weather map. Value of aircraft observations.

Stage D

17. *Air masses, depressions, fronts*.—Table showing origins and weather of tropical maritime, tropical continental, polar maritime and polar continental air masses. The Norwegian theory of the formation of depressions. Diagrams of depressions. Intimate relation between depressions and fronts. Warm and cold fronts and sectors; flying conditions in their vicinity; associated weather. Wind changes with fronts. Line-squalls.

18. *Other fronts*.—The occlusion; character and associated weather. Secondary fronts; character and associated weather. Flying conditions. Life history of a depression.

19. *Other types of pressure distribution*.—The anticyclone, secondary depression, trough of low pressure, wedge or ridge of high pressure, the col; character of each and associated weather.

20. *Clouds and precipitation*.—Orographic cloud and precipitation; examples. Convectional cloud and precipitation; examples. Gradual ascent of air over a large area; examples. Turbulence or eddy motion cloud; examples.

21. *Visibility*.—Visibility in rain and snow of different intensities. Visibility in fogs. Radiation, movement and mixing fog; how formed and when and where to be expected. Examples of each. Visibility in smoke haze; examples. Reduction of visibility by dust and sand; examples. Visibility from ground and air may be different; illustration. Visibility looking up and down sun tactical importance. Visibility in moonlight.

22. *Ice accretion*.—The types of ice accretion. Effects of severe icing-up of aircraft seen in increased drag and increased stalling speed, reduced engine power, interference with airscrews, control surfaces, fixed wing tip slots, wind-screens, sliding hoods, and emergency panels. How ice formation is combated. How supercooled water drops may cause ice formation. Conditions under which ice may form on aircraft. Rate of ice formation. Reasons why different types of ice form. Table showing conditions under which four main types may form, and their effects on aircraft. Table showing types of ice that may form in rain and in various cloud types. Meaning of freezing levels in forecasts; examples. Avoiding action, A.M.O. on ice accretion.

23. *Thunderstorms*.—Conditions necessary for formation of thunderstorms. Character of fully developed thunderstorms, with diagram and details of associated weather. Table showing three varieties of storms due to heating of atmosphere over land or sea, and two varieties of storm associated with fronts. Flying in storms; vertical currents, hail, lightning and icing considered. Flying advice when storms lie across intended track.

24. *Flying in clouds*.—The information aircrews need about clouds. Clouds best thought of as heap and layer types for their purposes. Table showing flying conditions in heap and layer clouds. Lessons to be drawn from this table. Formation flying in cloud.

25. *Wind*.—Gusts and bumps. Turbulence may go up to great heights. Diagram showing effects of obstacles on wind flow. How cliffs and ridges cause vertical currents; example of the Rock of Gibraltar. Thermal up currents; where met, and effects on flying. How wind velocity varies with height. Finding the most favourable flying level. Land and sea breezes; katabatic winds; examples of each. Nature of diurnal wind variation.

26. *Meteorology and operational flying*.—Operational importance of meteorology—importance of meteorological knowledge to aircrews; hints of flying in difficult conditions.

APPENDIX No. 8

SYLLABUS OF METEOROLOGICAL INSTRUCTION OF THE SPECIALIST 'N' COURSE AT THE CENTRAL NAVIGATION SCHOOL, CRANAGE (OCTOBER 1943)

METEOROLOGY

Organisation

1. (i) Importance of Meteorology in peace and war. Organisation of Meteorological service in war-time, at home and overseas, including organisation for overseas flights. Brief outline of peace-time international organisation.

(ii) Procedure for supply of forecasts and warnings to the Royal Air Force.

(iii) Standard hours of observations.

(iv) Observations and instruments in general use for surface and upper air reports.

(v) Codes for synoptic and abbreviated weather reports; special reports for sudden changes in meteorological conditions, squalls, etc.

(vi) Flying fitness figure.

(vii) The weather map. Methods of plotting data on aviation charts.

Physical Principles

2. (i) Composition of the atmosphere. Laws of gases.

(ii) Pressure and its variation with altitudes. Isobars and pressure gradient.

(iii) Wind. Relation to pressure gradient. Geostrophic and gradient wind measurement of surface winds. Structure of wind in lower layers (gustiness, turbulence squalls). Anometer records. Diurnal variation in surface winds. Variation with height near the surface. Local winds (Katabatic, land and sea breezes, contour effects). Fohn winds. Upper winds (measurement, variation with height and relation with horizontal temperature gradient, deduction of upper wind with from P.T. soundings, variation of upper wind with time at given place, and with place. (Vertical currents (orographic, convectional).)

(iv) The altimeter, international standard atmosphere and its application to altimeter calibration. Correction of altimeter readings for deviations of pressure from setting value and of temperature from ' standard value '. Detailed treatment of advantages of predicted meteorological corrections to altimeters as compared with use of navigational computer.

(v) Air Density. Its importance in aviation and variation with pressure and temperature.

(vi) Temperature.—Radiation, convection, conduction. Variation of temperature with height. Inversions, lapse rates and stability. Diurnal variation of temperature. Troposphere and stratosphere.

(vii) Moisture in the atmosphere; absolute and relative humidity, measurement of humidity. Dew point and condensation, nuclei. Tephigram and its use.

(viii) Cloud types; modes of formation, associated weather conditions, heights and thicknesses including methods of measurement. Cloud flying visibility within different types of cloud.

(ix) Condensation trails.

(x) Thunderstorms; atmospheric conditions giving rise to these storms. Brief account of recent research on electrical charges in clouds and on lightning. Indications of proximity of thunder (atmospherics, humming in inter-communication system, brush discharges). Precautions to be taken when flying in vicinity of thunder clouds.

(xi) Visibility, effects of dust, smoke and industrial pollution. Fogs; radiation, advection, fog forecasting. Effect of topographical features on fog development and of industrial pollution on the intensification of fog.

(xii) Ice accretion, physical causes. Types of ice accretion. General rules for avoiding dangers of ice accretion. Effect of speed of aircraft. Recent research.

Practical Work

3. (i) Meteorological observations making and coding reports for synoptic and abbreviated weather messages, including preparation of aerodrome fitness figure. Nephescope observations.

(ii) Plotting data on weather charts and drawing isobars (preliminary).

Synoptic Meteorology

4. (i) Meteorological conditions associated with different types of pressure systems with detailed consideration of the anticyclone.

(ii) Air masses and polar front theory of depressions. Fronts in detail. Effect of orographical features on the development of weather. Line squalls.

Practical Work

5. Plotting data, drawing isobars and inserting fronts (charts of progressive difficulty will be used in training).

Forecasting

6. (i) Estimating the movement and development of fronts and pressure systems. Short period forecasting. Information distributed by teleprinter in U.K. including forecasts and analyses.

(ii) Practical examples. Forecasts for longer periods. Details route forecasts.

Climatology

7. General circulation of the atmosphere. Surface and upper winds, pressure temperature and precipitation, over the earth in general with a special reference to the factors affecting aviation. Special attention to be paid to the European theatres of War, N. Atlantic, Mediterranean, Middle East, India.

Text Books

A.P. 1699	Meteorology for Aviators by R. C. Sutcliffe ..	(M.O. 432)
M.O. 247	Elementary Meteorology	Pick
A.P. 1931	Meteorology for Pilots and Observers ..	M.O. 448
A.P. 1875	Cloud Atlas for Aviators	M.O. 450

Reference Books

The Admiralty Weather Manual.
M.O. 420 (*a*), (*b*). Ice Accretion on Aircraft.
M.O. 336 (*f*). Lightning and Aircraft.
M.O. 191. Observers Handbook.
M.O. 255 (ii). Meteorological Glossary.
Climate of the Continents .. .. W. G. Kendrew
Climate .. .. W. G. Kendrew
' and several others '.

Note.—Synoptic divisions Technical Memoranda and Instructions and Meteorological Office Memoranda give up-to-date information on Condensation Trails, Ice Accretion, Altimeter Corrections, Methods, of observation, statistics of winds found by Radio Wind finding, and other matters.

APPENDIX No. 9

OPERATION NEPTUNE

SUMMARY OF RESULTS OF STATISTICAL EXAMINATION OF THE PROBABILITY OF OBTAINING SPECIFIED WEATHER CONDITIONS

In the months preceding the launching of operation NEPTUNE, examinations of weather statistics for past years were made from many different angles with a view to estimating the probability of obtaining specified weather conditions at various periods from April onwards. Some of the results obtained at various times, using different sets of basic information, were as follows :—

Defining a quiet day as one with wind less than Force 3 onshore and Force 4 offshore, on the Normandy Coast of France and stipulating the following overall requirements for the periods of the assault :—

(*a*) D Day be within the period of one day before to four days after new or full moon (that is assuming landing of Airborne troops could be affected irrespective of ground illumination from moonlight).

(*b*) D Day be itself quiet and followed by a sequence of three quiet days.

(*c*) Cloud less than 3/10 below 8,000 feet and visibility more than 3 miles.

(*d*) Alternative to (*c*), cloud base generally above 3,000 feet and with morning mist or fog not excluded.

The following arithmetical values were obtained for the probabilities of the various conditions (*a*), (*b*) (*c*) and (*d*) above :—

		May	*June*	*July*
		Chances to 1 Against		
(1)	(*a*) (*b*) and (*c*) together	24	13	50
	(*b*) and (*c*) without (*a*)	9	4½	19
	(*b*) and (*c*) with (*a*) limited to full moon	49	24	100
(2)	(*a*) (*b*) and (*d*) together	11	6	16
	(*b*) and (*d*) without (*a*)	4	2	5
	(*b*) and (*d*) with (*a*) limited to full moon	24	13	33

Of these various sets of conditions, the third set in the second group was the most likely to have to be accepted, viz. D to D plus 3 quiet as regards wind, cloud base generally above 3,000 feet and the conditions restricted in any one month to six days around full moon. Even with those conditions which did not cover the minimum requirements for some of the phrases of the operations, the chances of obtaining the conditions together over a set of days were very low, viz. 24 to 1 against in May, 13 to 1 against in June and 33 to 1 in July. One important result did come out from these and many other examinations, viz. that June was likely to be the best of the three early summer months. So that if the operation was planned for May and postponed, June, with better chances, was still to come ; but if the operation were planned for June and deferred, its chances of similar conditions in July (and subsequent months) would be less good than for May or June.

There were, of course, meteorological reasons for avoiding May for Channel operations if at all practicable ; one of these was the statistical frequency of occurrence of winds from between northeast and east in the eastern and central Channel area. These winds coming over the water of the cool North Sea bring low stratus cloud liable to persist with 10/10 cover for days at a time in the central and eastern Channel area.

APPENDIX 10

OPERATION NEPTUNE

WEATHER INFORMATION AND ADVICE FURNISHED TO THE SUPREME COMMANDER'S STAFF IN THE PREPARATORY STAGES (VIZ. ON 28, 29, 31 MAY AND 1 JUNE)

(1) In this period, during which decisions had to be taken for the sailing of those assault and naval bombardment forces which were coming from a considerable distance, it was recognised that no definite forecast could be given for conditions on and immediately following the scheduled D Day, 5 June.

(2) On Sunday, 28 May, the Supreme Commander was advised through the Assistant Chief of Staff, G–3 Division, SHAEF, that the evidence then was that mainly quiet wind conditions would continue during the week. Even in the present stable situation, nothing helpful could be said about wind or cloud conditions on D Day but the risk of conditions changing so much from what they are now as to produce a gale in the Channel then seemed rather small.

(3) On Monday, 29 May, to a meeting at 1000 hours at Portsmouth, of the Supreme Commander, his Commanders-in-Chief, and their Chiefs of Staff, the following forecast was presented for the five days until Friday, 2 June.

Mainly quiet wind conditions (not more than Force 4) throughout the period except for a wind of Force 5 in the extreme western Channel areas on Thursday and Friday.

Variable cloud conditions with an average of 5/10 to 7/10 except in local thunderstorms during the first two or three days ; cloud would probably increase from the west at the end of the period. The visibility would be good except for morning coastal haze and in thundery showers.

The confidence was given as moderate for continuation of quiet wind conditions but low for details of cloudiness and developments toward Thursday and Friday.

In course of questioning at this meeting about conditions for Saturday, 3 June, it was repeated that there was a risk of deterioration at that time especially as regards cloud conditions, but that the outlook was favourable from the viewpoint of wind in the Channel.

The basis of this advice was that there was no evidence to indicate that the existing northeasterly extension of the Azores high pressure area would be substantially modified in the next four or five days ; it was therefore a reasonable expectation that, even if it did begin to recede or collapse at the end of that time, it would still influence the movements and intensities of any low pressure systems that might affect the operational area by giving them a northeasterly track away from the English Channel.

(4) 0830, *Wednesday*, 31 *May*. The Assistant Chief of Staff, G–3, SHAEF, was advised that since Monday morning's conference at Portsmouth, the situation did not look as favourable as it then did for weather in the Channel area from Sunday, 4 June, onwards. But there was as yet no definite evidence that winds would be substantially above Force 4 for long periods ; nothing helpful could be said at that stage about cloud conditions on 4 and 5 June.

This advice was based on the prognostic analyses agreed by the forecasting centrals to the effect that there were indications that the Azores high pressure area was beginning to show signs of weakening, though there was time for a replacement high pressure area to move in or resuscitate it from the west.

(5) 0845, *Thursday*, 1 *June*. The A.C. of S., G–3 (General Bull), was advised that there was no new evidence to change the forecast as given him yesterday (para. (4)). The balance of evidence was that wind in the Channel area should continue not more than Force 4 over the weekend and on Monday, 5 June, but no forecast for cloud could be given. The confidence in operationally quiet wind conditions continuing into Monday was somewhat less than in the forecast given on Wednesday.

Summary of Meteorological Statements made at the Supreme Commander's Meeting at Portsmouth (Friday 2 June to Monday 5 June)

In their essentials, the statements are reproduced in as nearly as practicable the same form of words as were used at the meetings.

1000 *Friday*, 2 *June*

Winds in the Channel and particularly in the Normandy area will probably be westerly, mainly not above Force 4, but Force 5 at times particularly in the western channel towards the end of the period (Monday and Tuesday).

Cloud conditions on Sunday and Monday cannot be forecast with any degree of confidence ; they will be variable. Amounts will be 7/10 to 10/10 in the early morning in the operational area, clearing partially in the forenoon to 5/10 or less but with patches up to 10/10 for considerable periods.

Visibility will be moderate to good generally but with risk of fog patches in the Channel and coastal areas on Monday morning.

The general type of weather is westerly in which Force 5 winds cannot be ignored at any time and in the warm humid air brought across the Atlantic from lower latitudes, cloud conditions are always uncertain particularly over higher ground in coastal areas and in the southwest of the Channel area.

There is now indication that the present relatively quiet weather may end about Tuesday.

2130 *Friday*, 2 *June*

The general meteorological situation has not changed substantially and the forecast presented at the morning conference still stands. The flow of moist warm air over the operational areas will produce much low cloud. The whole development is at the moment sluggish and slow to show its hand ; but, on the whole, the outlook for Sunday and Monday

seems not unfavourable from the point of view of wind speed, namely, mainly Force 4 ; but there is a risk of Force 5 winds on Tuesday. The outlook for cloudiness is very uncertain ; considerable period of 10/10 cloud cover with base about 1,000 feet must be expected. The times of the periods cannot be forecast accurately.

To a question (Supreme Commander) about conditions on Tuesday and Wednesday the reply was that the evidence at present did not indicate much difference on those days from the conditions as just described for Sunday or Monday ; there was no basis for forecasting persistent high winds though there was a risk of Force 5 on Tuesday ; cloud conditions would probably continue poor with periods of 10/10 at 1,000 feet.

Another inquiry (D/Air C.-in-C. General Vandenburg) was directed to conditions for the transport and landing of Airborne troops overnight Sunday–Monday. The reply was that cloud base would probably be mainly above 1,000 feet but there would be patches with base at or below 1,000 feet after 0200 on Monday morning.

0800, *Saturday*, 3 *June*

A.C. of S., G-3 (General Bull) was informed by telephone that there was no indication of improvement from the terms of the forecast presented at 2130 the previous evening. But the risk of Force 5 winds then forecast for Tuesday had now to be brought into Monday and even the latter part of Sunday. The view at the moment was that these Force 5's would be mainly on the English Channel coast.

The cloud forecast is still very uncertain ; the most likely cloud conditions are 7/10 to 10/10 base 1,000 feet, especially in the early morning hours. No opinion can be expressed about exact times of clearances, except for areas well inland during the afternoon.

General Vandenburg (D/Air C.-in-C.) and Admiral Creasy (C. of S. to Naval C.-in-C.) were given the same information. It was emphasised that the synoptic situation had become an extremely difficult one, and forecasts as to details were given with low confidence.

2130, *Saturday*, 3 *June*. Supreme Commander's Meeting

The high pressure area over the Azores is rapidly giving way and a series of depressions across the Atlantic is moving rapidly eastward ; these depressions will produce disturbed conditions in the Channel and assault area.

Winds will be west-southwest, Force 5 on English coast. Force 3–4 on the French coasts from early Sunday, until a cold front trough passes. That passage is timed to be sometime on Wednesday, 7 June.

From Sunday morning onwards, cloud will probably be mainly 10/10 with base 500–1,000 feet in the morning hours. This cloud may break in inland areas during the day and become about 5/10, but will continue of variable amounts in the Channel area and on both coasts with considerable patches of 10/10 ; its base will be at or below 1,000 feet. The time of incidence and local distribution of these patches of low cloud cannot be forecast with confidence.

Some patches of medium and high cloud, mainly confined to South England must also be expected ; amounts of this type of cloud will be less in areas well inland, *e.g.* over the Eastern Midlands and over the East Anglia bomber base areas.

Visibility will be mainly 3–4 miles, though 5–6 miles inland in the afternoon can be expected. There is a risk of fog spreading from the West up the Channel to sea and coastal areas. After Monday this risk of fog will decrease.

These details cover the period Sunday to Tuesday and at first on Wednesday, as far as can be seen with any confidence at the moment.

During Wednesday, a front associated with a depression now off Nova Scotia and the New England States will probably pass through the assault area.

Just preceding this front there will be a period of 10/10 multilayer cloud (low, medium and high) ; then as the front passes there will be a decrease of cloud amount and increase of cloud base heights, becoming 5/10 to 2,500 feet. Visibility on Wednesday will be moderate at first becoming good after the front passes.

Further meteorological forecasts and statements made at this meeting were as follows :—

(*a*) Air C.-in-C., on a question about likely conditions for heavy bombers taking off from bases early on Monday morning :

10/10 stratus cloud, base 500–1,000 feet and about 3,000 feet thick ; with a second layer of medium cloud base between 8,000 feet and 12,000 feet. This second upper layer will probably not be a continuous 10/10ths sheet.

(*b*) Air C.-in-C., about conditions for enemy aircraft using their own bases :

Cloud along the French coasts will probably be 10/10, base 500–1,000 feet ; but inland, away from the coastal strip, cloud amounts may be expected to be less during the middle part of the day. Conditions over enemy bases on Monday will, on the whole, be better than over bases in England.

(*c*) Naval C.-in-C., whether Force 5 winds along the English Channel are likely to continue through Monday and on Tuesday. Force 5 winds must be expected on Monday and Tuesday.

(*d*) Naval C.-in-C. ; would cloud conditions also be similar on Tuesday.

Similar cloud conditions will probably continue from about Sunday forenoon until Wednesday, when the clearing front is due to pass through the operational areas.

No useful forecast can be given beyond that at present.

(*e*) To a general question about probable weather conditions after Wednesday, the reply was that weather could not be expected to settle down quickly after the present very disturbed situation. But the prospects were, alternating of periods of greater and less cloudiness with mainly moderate westerly wind though fresh at times, associated with minor fronts and ridges of high pressure.

(*f*) The Supreme Commander commented on the slightly more optimistic note that he felt had come into the picture between the morning and evening conferences on Friday ; and asked whether the forecast might not be more optimistic again tomorrow morning.

There is very little chance of any information being received before 0300 which is likely to give a more optimistic turn to the forecast. Since at least yesterday (Friday) morning, the whole meteorological situation has looked very unpropitious for a Monday assault but the outlook has been finely balanced in that it might have swung to better or much worse. On Friday evening there was a very slight tip of the balance on the favourable side but the balance now has swung too far to the unfavourable side for it to be quickly counteracted. The Supreme Commander said that he had certainly been left on Friday with the impression that the situation was both difficult and uncertain.

(*g*) Deputy Supreme Commander asked whether the meteorological centrals were all agreed about the forecast as presented.

The centrals have agreed to accept the forecast.

(Following the presentation of this information, the assault was provisionally postponed for 24 hours.)

0415, *Sunday*, 4 *June*

No new evidence has been received which allows any substantial change in the forecast presented last (Saturday) evening. The only small change is that the front which was then expected to clear the Channel areas of low cloud on Wednesday, is now expected in the first part of Wednesday.

Winds will be Force 5 in the Channel from early Monday onwards, though somewhat less in sheltered areas on the French coast.

10/10ths cloud, base 500–1,000 feet are expected along the Channel area, with no forecastable difference in these conditions from Sunday to Tuesday.

The Naval C.-in-C. asked when these overcast skies would appear at Portsmouth, commenting that it was a practically clear sky with calm wind at the time of the meeting. He was advised that the cloud would increase during the early forenoon, of that day (Sunday).

(Following this presentation the time of the assault was deferred by 24 hours in the first instance.)

1745, Sunday, 4 June

A.C. of S., G–3 was informed that there had been a substantial change in the situation since the early morning. It is now likely that there will be a fair interval starting about midnight today and lasting till about dawn on Tuesday morning. During this fair interval, and particularly from Monday evening to Tuesday morning, cloud amounts will probably be substantially smaller than given in forecast this morning ; winds will also moderate temporarily, particularly over Monday night and at first on Tuesday.

A deterioration will probably set in again during Tuesday ; weather on subsequent days will continue unsettled and disturbed.

On General Bull's request this same information was conveyed to General de Guingand (Chief of Staff to Army C.-in-C.).

2100, *Sunday, 4 June*. Supreme Commander's meeting.

Since the statement made before the meeting on Saturday evening, there have been some rapid and unexpected developments in the weather situation over the Atlantic. A front from one of the deep depressions in the northwest Atlantic has moved much farther south than was expected and is now traversing the Channel areas. It is almost over Portsmouth now and will clear the eastern Channel at least on the English side overnight. When that front has passed there will be an interval of fair conditions which, from the evidence we now have, should last until at least dawn on Tuesday.

Wind speeds by Monday evening should decrease to Force 3–4 on the French Channel coasts and cloud will become mainly less than 5/10, with base 2–3,000 feet.

After that interval, lasting till Tuesday morning, cloud will probably increase to 8/10–10/10 from the west during Tuesday afternoon and will continue so overnight Tuesday.

From a time on Wednesday which cannot be defined from present information, mainly cloudy conditions will continue ; but there should be some intervals of broken cloud. In this period from Wednesday to Friday, there will probably be intervals of 10/10ths cloud with base at 1,000 feet ; these overcast intervals of low cloud may be expected to last 4–6 hours at a time.

Wind will be mainly Force 4 on the English Channel coasts and Force 3–4 on French Channel coasts ; in sheltered stretches of the French Channel coast periods of Force 2–3 could be expected. The wind direction throughout will be Westerly.

Additional meteorological statements were made at this meeting in reply to specific questions as follows.

Admiral Creasy (C. of C. to Naval C.-in-C.) asked if there was a chance that conditions from Wednesday to Friday might be better than those described in the main statement. He was advised that there was a reasonable chance that the weather systems which were expected to cause the temporary deteriorations after Tuesday would follow a more northeasterly track to Iceland or Southeast Greenland and if that happened the cloud conditions would probably be better than those now forecast. But nothing definite could be said at present about such future developments.

General Eisenhower asked if anything could be said about conditions beyond Friday. He was advised that the forecast even up to then could not be given with any substantial confidence. The general weather conditions must continue to be regarded as disturbed and unsettled ; after the very vigorous shake-up in the whole synoptic situation over the North Atlantic which we are going through now, conditions cannot settle down immediately.

But considering the time of year and the evidence we now have, there is a reasonable prospect of weather slowly improving after Friday if the present trend of development over the period Wednesday to Friday comes out as now expected.

A.C.M. Tedder asked about the confidence in the forecast. In reply it was explained that pressure systems had formed, deepened and crossed the Atlantic at a rate appropriate to mid-winter. Confidence in the forecast for more than a short period ahead cannot be high ; but there is a fair chance that the low pressure system now in the Newfoundland area will move on a northeasterly track and more slowly than its predecessors ; if developments go that way, that should give the azores high pressure system a chance to build up again and at least partially to protect the Channel areas from future depressions traversing the Atlantic from the west.

To A.C.M. Leigh-Mallory and General de Guingand who asked about the detailed cloud conditions expected overnight Monday–Tuesday, the information given was that following the clearance on Monday, cloud over the assault areas and the immediate hinterland would probably remain well broken from midnight Monday to Tuesday morning. The base of this cloud would probably be about 2,500–3,000 feet and could be expected to be not more than 5/10ths at any time in that area.

Asked by A.C.M. Leigh-Mallory if his meteorological advisers at H.Q., A.E.A.F., agreed with views presented at this meeting, the reply was that they did ; their view was that good though not uninterrupted conditions for visual bombing heavy and medium bombers could be expected from Monday evening till early forenoon Tuesday ; then periods of good bombing alternating with poorer periods after the deterioration on Tuesday–Wednesday had passed.

Naval C.-in-C., commenting on conditions for operation of spotting aircraft for naval bombardment, which required cloud base heights not below 2,500 feet, was assured that conditions would probably be favourable for these spotting and reconnaissance operations.

(Following this meeting, provisional instructions were issued for launching the assault at 0630 on Tuesday morning.)

0415, *Monday, 5 June*

There has been no substantial change in the information available since, or in the forecast presented at, the meeting yesterday (Sunday) evening.

The fair to fine interval which by 0415 had begun at Portsmouth will probably last into the forenoon of Tuesday. During this interval, cloud will be mainly less than 5/10ths, with base at 2,500–3,000 feet.

Wind on the beaches in the assault area will probably not exceed Force 3 in this interval and will be westerly. Visibility will be good.

During Tuesday, cloud will very probably increase again from the west giving a period of overcast sky with cloud base at about 1,000 feet in the assault area later in the day ; these cloud conditions will continue overnight Tuesday–Wednesday. Winds will be westerly Force 4 on the English coasts and mainly Force 3 on the French coasts.

Conditions will probably continue unsettled after Tuesday and it is difficult to time further changes. But it is likely that after another front has passed on Wednesday when the 10/10ths cloud at 1,000 feet lasting over Tuesday night become broken, the cloud base will increase to 2,000–3,000 feet though the average amount will probably remain at about 7/10ths. In this period from the passage of Wednesday's front till about Friday, beyond which no useful forecast can be given, there will be intervals of completely overcast sky with cloud base down to 1,000 feet. Considerable fair periods of broken cloud can reasonably be expected between the overcast intervals. Visibility will be good throughout.

A.C.M. Tedder said that on Friday and Saturday, the effects of moist warm air coming into the Channel and producing much low stratus cloud had been prominent in the forecast presented. What had happened to clear this air from the Channel so quickly ?

There had been considerable doubt about the real synoptic situation on the Atlantic over the last 48 or 60 hours. It had been considered that a front trailing from one depression now off northwest Scotland was bent away sharply to the west into another low pressure system off Nova Scotia and Newfoundland and that this front did not extend far enough south to come through the Channel areas. This analysis had been faulty mainly because of inaccurate and inadequate reports. The front had actually swept down southwestward and crossed the northern coasts of the Central Channel in the last few hours.

In answer to other questions at this meeting, the following information was given :—

(1) There is a reasonable chance after Wednesday of further low pressure systems from the western Atlantic taking a more northeasterly course into the Iceland area instead of towards northwest Scotland ; if this occurs, the fronts associated with these low pressure systems will not have such an intense effect on the wind and cloud conditions in the Channel and French coasts.

(2) The situation even after Wednesday must continue to be regarded as disturbed ; a quiet settled spell cannot be expected to start immediately after such an intensely disturbed situation. But the time of year suggests that changes after Wednesday may be expected to be in the direction of improvement rather than of renewed or further deterioration to the present intensity.

(Following this meeting, the final and irrevocable decision to launch the assault on Tuesday morning was taken.)

0845, *Monday*, 5 *June*

A.C. of S., G–3 (General Bull) was informed by telephone (1) that there was nothing further to add to the forecast presented at 0415 and (2) that recent reports had shown that the clearance in cloud cover which had set in at Portsmouth in the early morning hours had not reached the area where the assault would have been taking place until at least 0600. Conditions there were 10/10 low cloud, base at about 1,000 feet and had been so throughout the night. Airborne landings and medium bomber support would almost certainly have been impracticable ; heavy bombers would have had no opportunity for visual bombing and aircraft spotting for naval bombardment would also have found conditions impracticable. Winds had been and continued a good Force 4 on the beaches.

APPENDIX No. 11

THE WEATHER IN NORMANDY AND THE CHANNEL

(i) *Period* 4 *to* 9 *June* 1944

This is a summary of the main weather phenomena actually observed during the most critical period, 4 to 9 June, in the Channel and Normandy beachhead.

The summary has been compiled from notes based on reports from operational aircraft and naval vessels and on reports transmitted back by the earliest Meteorological Sections to land with the Expeditionary Forces.

Sunday, 4 *June* :

0100	*Wind* :	WSW, Force 2–3.
	Cloud :	2–3/10 high.
0400	*Wind* :	WSW, Force 3.
	Cloud :	No low cloud over beachhead, 9/10, base 1–2,000 feet in Cherbourg Peninsula.
1000	*Wind* :	WSW, Force 3–4.
	Cloud :	Variable high cloud. Low cloud on Cherbourg Peninsula dissipated to 2–3/10.
After 1000	*Wind* :	WSW, Force 3–4.
	Cloud :	Small amounts over Channel and Northern France.

Monday, 5 *June* :

Prior to 0400	*Wind* :	WSW, Force 5.
	Cloud :	10/10 multi-layer cloud.
0400	*Wind* :	W, Force 4–5.
	Cloud :	10/10, base 1–2,000 feet.
0700	*Wind* :	W–WNW, Force 4.
	Cloud :	10/10, base 1,500 feet.
1300	*Wind* :	W, Force 3–5.
	Cloud :	7–10/10, base 3–4,000 ft.
1800	*Wind* :	W, Force 4.
	Cloud :	7–10/10, base 4–6,000 feet with broken cloud at 2,000 feet.

Tuesday, 6 *June* :

0100	*Wind* :	W, Force 3.
	Cloud :	7–10/10, base 3–5,000 feet.
0400	*Wind* :	WNW, Force 3.
	Cloud :	4–6/10, base 3,000 feet.
0545	*Cloud* :	Beachhead clear, with 6/10 low cloud inland.
0800	*Wind* :	WNW, Force 3–4.
	Cloud :	7–9/10, base 3,000 feet, tops near 7,000 feet, with 10/10 medium cloud above 11–12,000 feet.
Late Forenoon	*Cloud* :	Clouds broke and cleared over Channel.
1700	*Wind* :	WNW, Force 4, 5 at times.
	Cloud :	Clear conditions over Channel. Variable amounts of low cloud, mainly 6–9/10 over beachhead and further inland. There was a clear area over the Seine Estuary.
1800	*Cloud* :	At Cherbourg, 4–6/10, base 3–5,000 feet ; at Havre, 1–2/10 low cloud, 2–3,000 feet, with patchy medium.

Wednesday, 7 *June* :

0100	*Wind* :	WNW, Force 4.
	Cloud :	At Havre, 9/10, base 2–3,000 feet.
0700	*Wind* :	WNW, Force 4.
	Cloud :	Low cloud became more broken.
During Day	*Wind* :	NW, Force 4, decreasing to Force 3.
	Cloud :	Large amounts mainly 2,000 but 1,000 feet locally in showers at first, decreasing and lifting in afternoon. Small amounts at times later, especially near coast.
1800	*Wind* :	At Havre, N–NW, Force 2–3.
	Wind :	2–3/10.
1800–2100	*Cloud* :	Variable, 4–6/10, base 2,000 feet in beachhead and inland.

Thursday, 8 *June* :

0100	*Wind* :	NW, Force 3–4, Force 4–5 in Channel.
	Cloud :	Small amounts in Channel, 9/10 broken low cloud Le Havre base 2–3,000 feet.
0400–0700	*Wind* :	WNW, Force 3–4, Force 4–5 in Channel.
	Cloud :	Small amounts of cloud over the Channel, 2–3/10 beachhead area, maximum Le Havre, base 3,000 feet.
Forenoon	*Wind* :	WNW, Force 4, Force 4–5 in Channel.
	Cloud :	Small amounts of low and high cloud, base 1–2,000 feet.
Afternoon and Evening	*Wind* :	W, Force 4, increasing to Force 6 by 1800 hours, Force 5 in Channel.
	Cloud :	Increasing multi-layer cloud, base of low cloud 1,000–1,550 feet rain beginning 1600–1800 hours.

Friday, 9 June :

0100–0400	*Wind :*	W–WSW, Force 5, Force 6 in Channel.
	Cloud :	10/10 multi-layer, base 500–1,000 feet, light rain.
0400–0700	*Wind :*	WSW, Force 3–4, Force 4–5 in Channel.
	Cloud :	10/10 multi-layer cloud, base 1–2,000 feet, locally 500 feet, light to moderate continuous rain.
0700–1300	*Wind :*	WSW–WNW, Force 5, Force 6 in Channel.
	Cloud :	10/10 multi-layer cloud, base 1,000 feet, light intermittent rain.
Afternoon and Evening	*Wind :*	NW, Force 4, Force 5 in Channel.
	Cloud :	4–6/10 low cloud, occasionally overcast, base 1–2,000 feet, occasional showers.

(ii) *Period* 17 *to* 21 *June*, 1944 :

Saturday, 17 June :

0100	*Wind :*	NW, Force 4, Force 5 in Channel.
	Cloud :	Overcast, ceilings near 2–3,000 feet.
Forenoon	*Wind :*	N, Force 5, Force 6 in Channel.
	Cloud :	Overcast, ceilings near 2–3,000 feet.
Afternoon	*Wind :*	N, Force 4, but Force 6 and 7 in Straits.
	Cloud :	2–3/10, ceilings near 2,500 feet, scattered showers.
Evening	*Wind :*	N, Force 3–4, Force 6 and 7 in Straits.
	Cloud .	Cleared at beachhead.

Sunday, 18 June :

0100	*Wind :*	NE, Force 3–4, Force 4–5 in Channel.
	Cloud :	Overcast conditions, ceilings near 2–3,000 feet.
Forenoon and Afternoon	*Wind :*	NE, Force 4, Force 5 in Channel.
	Cloud :	Broken, ceilings near 3,000 feet.
Evening	*Wind :*	N–NE, Force 2–3, Force 3–4 in Channel.
	Cloud :	Multi-layer clouds, causing overcast conditions.

Monday, 19 June :

0100–0400	*Wind :*	NE, Force 4, Force 5 in Channel.
	Cloud :	Overcast conditions thickened, light rain, ceilings 1–2,000 feet.
During Day	*Wind :*	NE, Force 5 and 6, Force 6 and 7 in Channel.
	Cloud :	Light to moderate rain persisted, ceilings below 500 feet.
2200	*Wind :*	NE, Force 5, increasing to Force 6 and 7 in Channel.
	Cloud :	Broke to 9/10, rain intermittent, ceilings near 3,000 feet.

Tuesday, 20 June :

0100–0400	*Wind :*	NE, Force 5 and 6, Force 6 and 7 in Channel.
	Cloud :	Multi-layer clouds cleared, and small amounts were observed.
0400–forenoon	*Wind :*	NE, Force 5 and 6, Force 6 and 7 in Channel.
	Cloud :	Stratocumulus cloud cover developed, ceilings near 1,000 feet.
Forenoon and Afternoon	*Cloud :*	Cloud deck persisted in forenoon but broke to small amounts during afternoon.
After 1800	*Wind :*	ENE, Force 6, NE, Force 6 and 7 in Channel.
	Cloud :	Low cloud deck re-formed, ceilings near 1,000 feet.

Wednesday, 21 June :

0100–Afternoon	*Cloud :*	Overcast conditions, ceilings between 500 and 1,000 feet.
Late Afternoon	*Wind :*	NE, Force 5 and 6, NE, Force 6 in Channel.
	Cloud :	Small amounts of cloud.

APPENDIX No. 12

GENERAL SECURITY PRINCIPLES FOR SUPPLY OF METEOROLOGICAL INFORMATION TO CIVIL AVIATION

The general security principles for the supply of meteorological information to pilots of civil aircraft were as given in the following extract from the Standing Instructions for Civil Aircraft Operation (S.I.C.A.O.) agreed before the war between the Meteorological Office and Directorate General of Civil Aviation :—

1. Pilots of British and Allied Civil Aircraft

(*a*) Pilots of British and Allied civil aircraft have access to the Meteorological Office for discussion of the weather conditions and consideration of the latest synoptic charts.

(*b*) Prior to departure, such pilots will be furnished verbally with the fullest possible meteorological information covering the stage of the flight which they are to undertake, including anticipated landing conditions at the aerodrome for which they are bound.

(*c*) The Aircraft Landing Code (ALC Code) is available for use, and should be used when operating over the United Kingdom. In the case of the Empire flying boat services in particular the ALC Code should be used for requesting weather reports from Poole. The ALC Code has been prepared to provide a secure means of passing meteorological information from the ground to aircraft about to land. Instructions for the preparation and decoding of messages are given in Annex 1 to these Instructions.

(*d*) Pilots of British aircraft should not discuss with neutral pilots the conditions encountered in flight.

2. Pilots of Neutral Civil Aircraft

Meteorological information supplied to pilots of neutral aircraft will be issued verbally, and must be restricted to the minimum consistent with safety of the flight. The forecast will be confined, as far as possible, to an indication that the weather is, or is not, safe for the proposed flight. It will include, whenever possible, an estimated value for aerodrome-level pressure (QFE), and the anticipated weather conditions for landing, at the aerodrome of destination.

The latest available weather reports from stations along the route will also be supplied.

3. Pilots of British Allied and Neutral Civil Aircraft

(*a*) Meteorological information will not normally be transmitted by radio to aircraft in flight, except as stated in sub-para. 1 (*c*) above. In exceptional circumstances, when it appears desirable in the interests of the safety of the flight, advice may be transmitted to the pilots of Empire flying boat or landplane services when operating outside the United Kingdom, in one of the following forms :—

(i) A navigational instruction drawn up by the Air Traffic Control Officer on the basis of advice supplied to him by the Meteorological Officer. This instruction will not contain meteorological information, which may not be passed by radio in plain language.

(ii) In extremely urgent cases, a weather report sent in the confidential weather code for aircraft in flight. This method can be used only in the case of aircraft of operating companies to whom the confidential weather code has been issued, and *will not normally be used* except for long distance flights overseas.

(iii) As given in Appendix 'B', para. 3 (*a*), of Instructions for Scheduled Service Operation (I.S.S.O.) Nos. 8 and 13.

(*b*) No written statement of any kind regarding weather will be supplied to pilots.

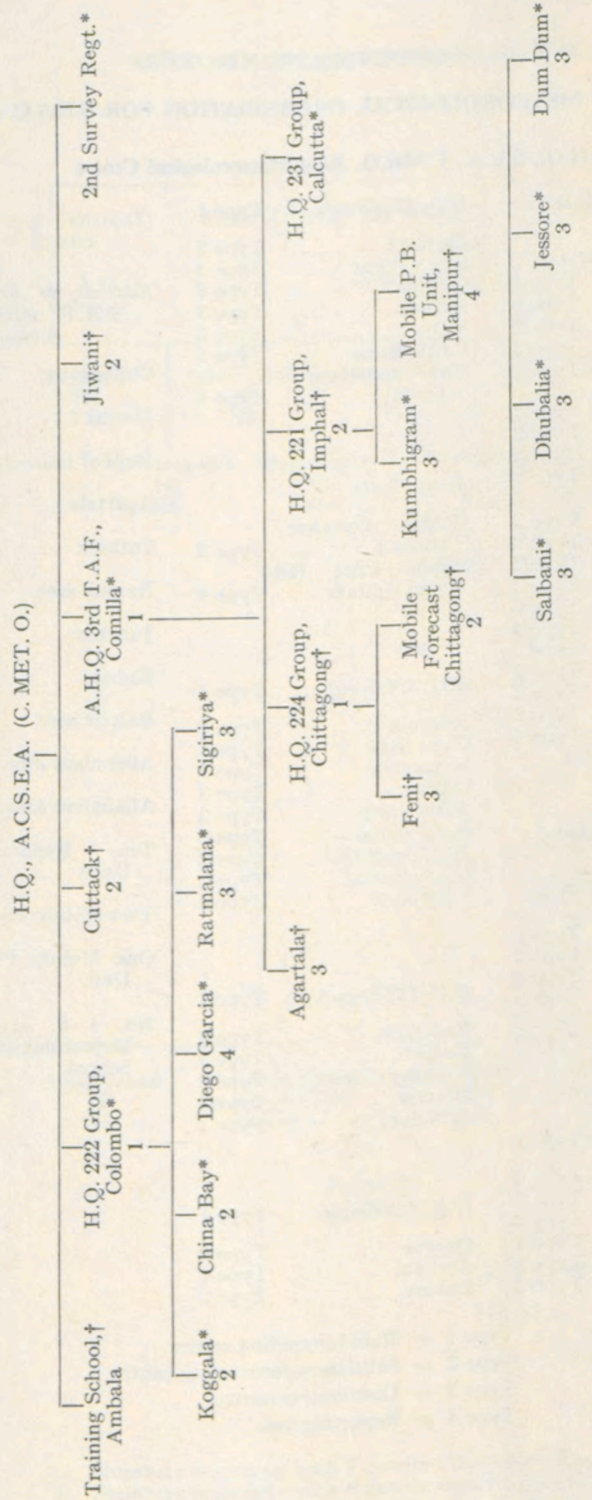
(*c*) No meteorological reports may be transmitted from the aircraft during the flight.

(*d*) The meteorological information supplied is confidential, and every precaution must be taken by pilots of aircraft and other persons concerned, that it is not divulged, in whole or in part, to any unauthorised person.

Note.—The A.L.C. landing code remained in use for internal civil aviation throughout the war as the operating companies were unwilling to accept Alametco when that code was introduced.

APPENDIX No. 13

METEOROLOGICAL ORGANISATION 1 APRIL 1944



* R.A.F.
† I.A.F.
Numbers refer to Type of Station, *i.e.* 1 = Main forecasting centre.
2 = Subsidiary forecasting centre.
3 = Distributive centre.
4 = Reporting unit.

APPENDIX No. 14

PROPOSED METEOROLOGICAL ORGANISATION FOR S.E.A.C.—1944

H.Q., S.E.A., C.Met.O. Joint Meteorological Centre

H.Q. B.A.F.S.E.A. S.Met.O.

H.Q. 229 Group S.Met.O.

Karachi ..	.. Type 1
Palam ..	.. Type 2
Allahabad	.. Type 2
Santa Cruz	.. Type 2
Madras .. (St. Thomas Mt.)	.. Type 2
Nagpur ..	.. Type 2
Vizagapatam	.. Type 2
Jodhpur ..	.. Type 2
Gwalior .. (Maharajpur)	.. Type 2
Ahmedabad	.. Type 2
Bhopal ..	.. Type 2
Hakimpet	.. Type 2
Cochin ..	.. Type 2
Trichinopoly	.. Type 2
Yellahanka	.. Type 3
Chaklala ..	.. Type 2
Jharsuguda	.. Type 2
Aurangabad	.. Type 2
Poona ..	.. Type 2
Drigh Road	.. Type 3

Eastern Air Command S.Met.O.

H.Q. 231 Group ..	Type 1
Salbani ..	.. Type 2
Jessore ..	.. Type 2
Dum Dum	.. Type 2
Digri ..	.. Type 3
Dhubalia ..	.. Type 2
Chakulia	.. Type 2

H.Q. 221 Group ..	Type 1
Kumbhigram	.. Type 2
Palel ..	.. Type 2
Tamu ..	.. Type 2
Palel ..	.. Type 4
Tamu ..	.. Type 4
Tulihal ..	.. Type 2

H.Q. 224 Group ..	Type 1
Chiringa ..	.. Type 3
Cox's Bazar	.. Type 3
Comilla ..	.. Type 3
Ratnap ..	.. Type 3
Nazir ..	.. Type 3
Bawli Bazar	.. Type 3
Two Reporting Units ..	.. Type 4

Army Units

Mobile Forecast Units 3 ..	Type 2
Mobile Pilot Balloon Units 6 ..	Type 4

H.Q. 222 Group ..	Type 1
Koggala ..	.. Type 2
China Bay	.. Type 2
Minneriya	.. Type 2
Sigiriya ..	.. Type 3
Addu Atoll	.. Type 2
Ratmalana	.. Type 3
Kankesanturai	.. Type 2
Diego Garcia	.. Type 2
Vavuniya	.. Type 4

H.Q. 225 Group ..	Type 1
Red Hills	.. Type 2
Kolar ..	.. Type 3
Korangi Creek	.. Type 2
Madura ..	.. Type 2
Arkonam ..	.. Type 2

H.Q. 223 Group ..	Type 1
Quetta ..	.. Type 2
Ambala ..	.. Type 2
Lahore ..	.. Type 2

Stations to be staffed by I.A.F. meteorological personnel

Chittagong	.. Type 1
Jiwani ..	.. Type 2
Imphal ..	.. Type 2
Agartala ..	.. Type 2
Cuttack ..	.. Type 2
Raipur area	.. Type 2
Junchar ..	.. Type 3
Kohat ..	.. Type 3
Raipur area	.. Type 3
Allahabad area ..	Type 3
Allahabad area ..	Type 3
Ten Reporting Units ..	.. Type 4

Two Mobile Forecast Units

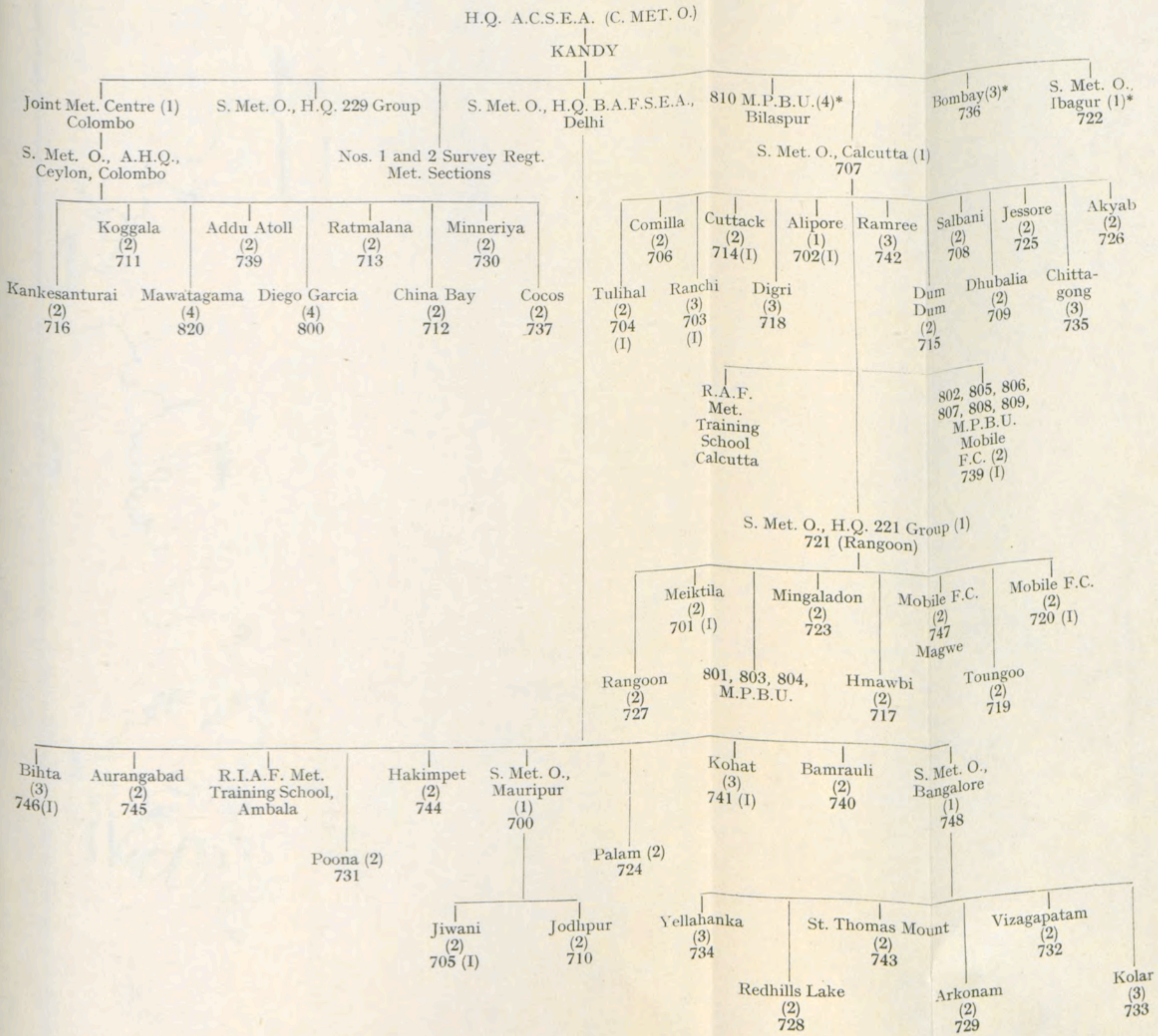
One Mobile Pilot Balloon Unit.

No. 1 S. of A.F.T.T.(I) Meteorological Training School.

Type 1 = Main forecasting centre.
Type 2 = Subsidiary forecasting centre.
Type 3 = Distributive centre.
Type 4 = Reporting unit.

APPENDIX No. 15

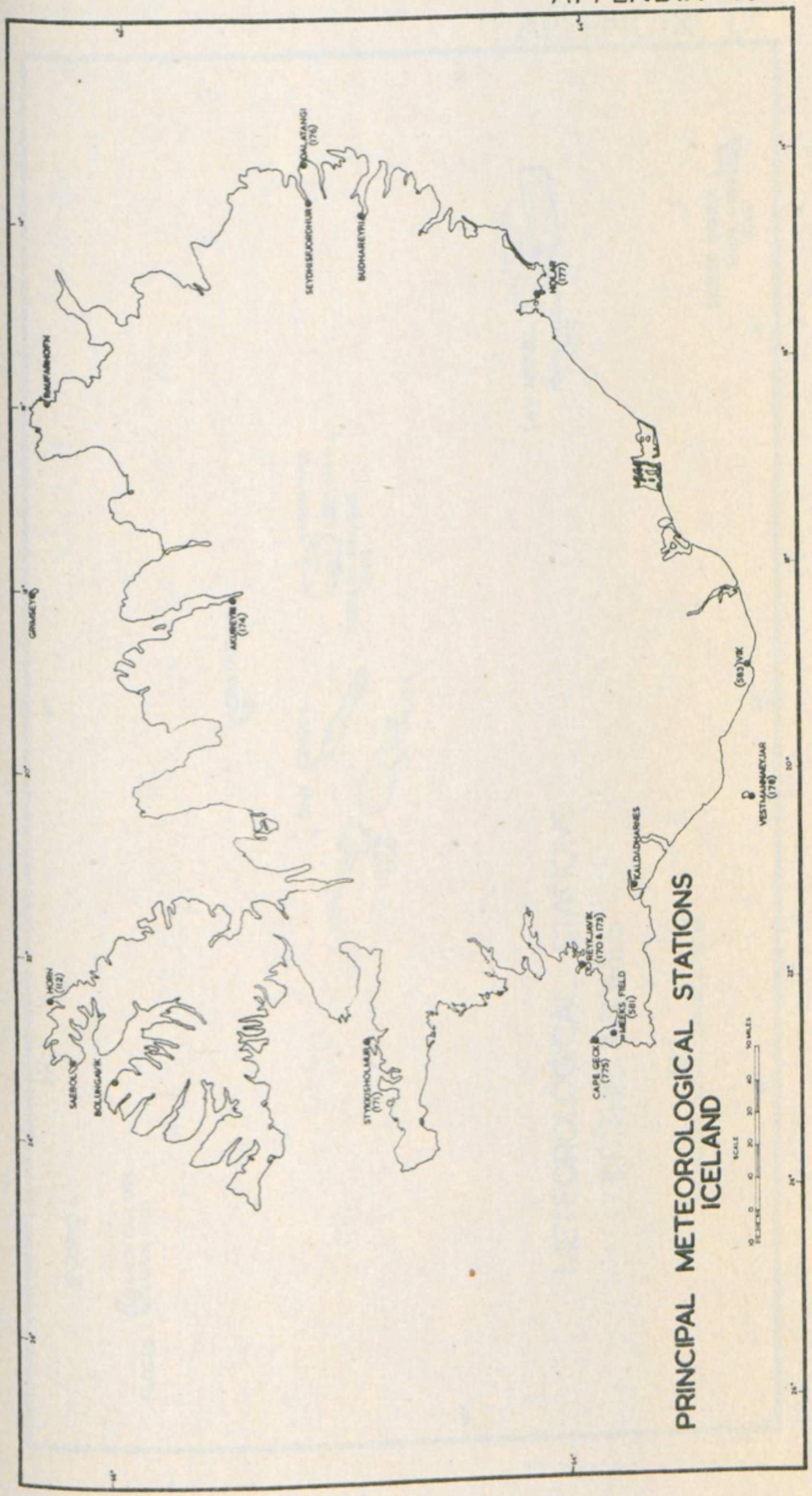
METEOROLOGICAL ORGANISATION IN AUGUST 1945 IN AIR COMMAND SOUTH-EAST ASIA



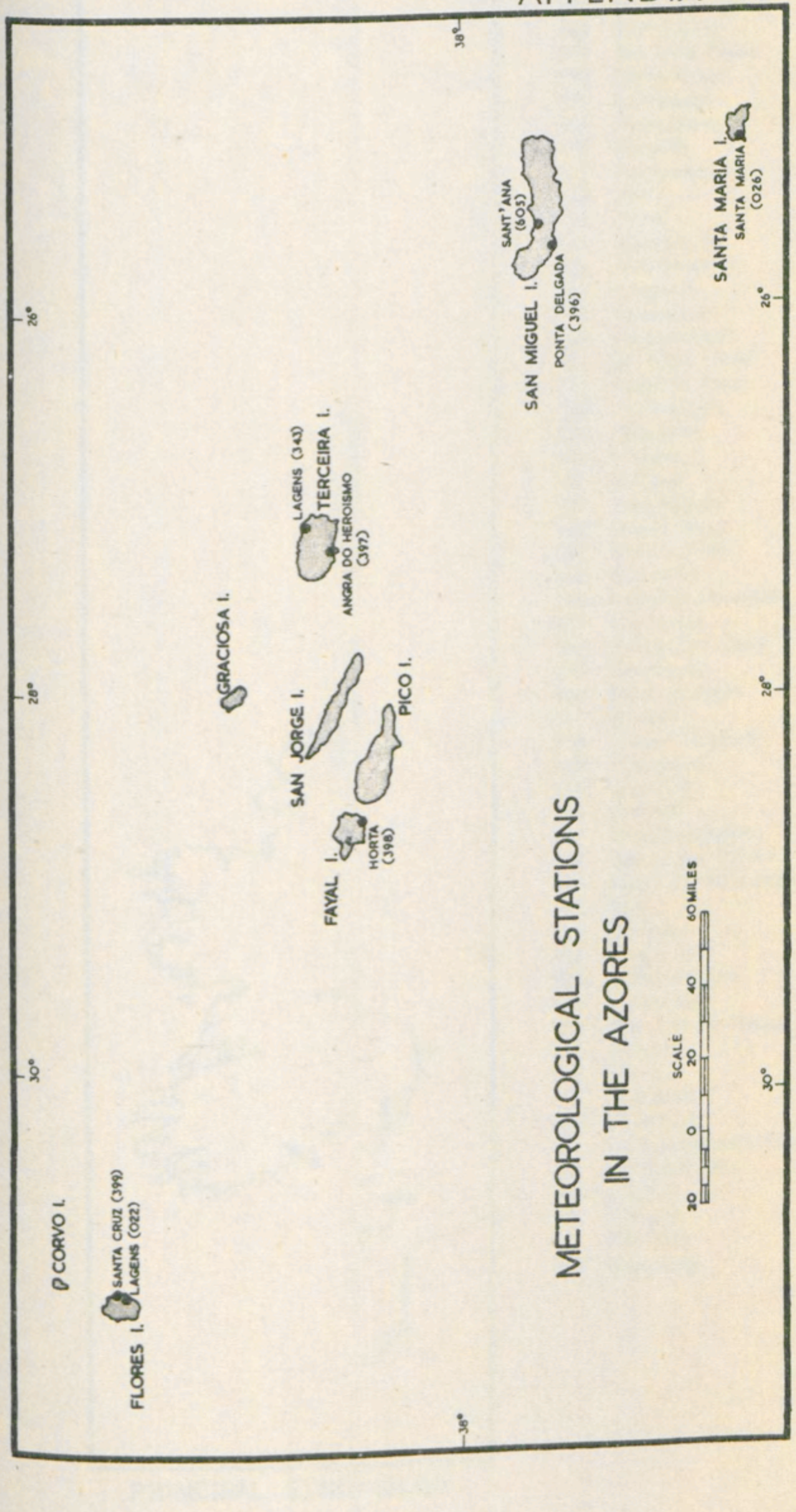
NOTES

1. Numbers beginning with 7 denote Forecast Centres.
2. Numbers beginning with 8 denote reporting units.
3. Numbers in brackets indicate type of stations.
4. (I) denotes R.I.A.F. units.
5. M.P.B.U. indicates mobile pilot balloon unit.
6. * Units en route to Malaya.

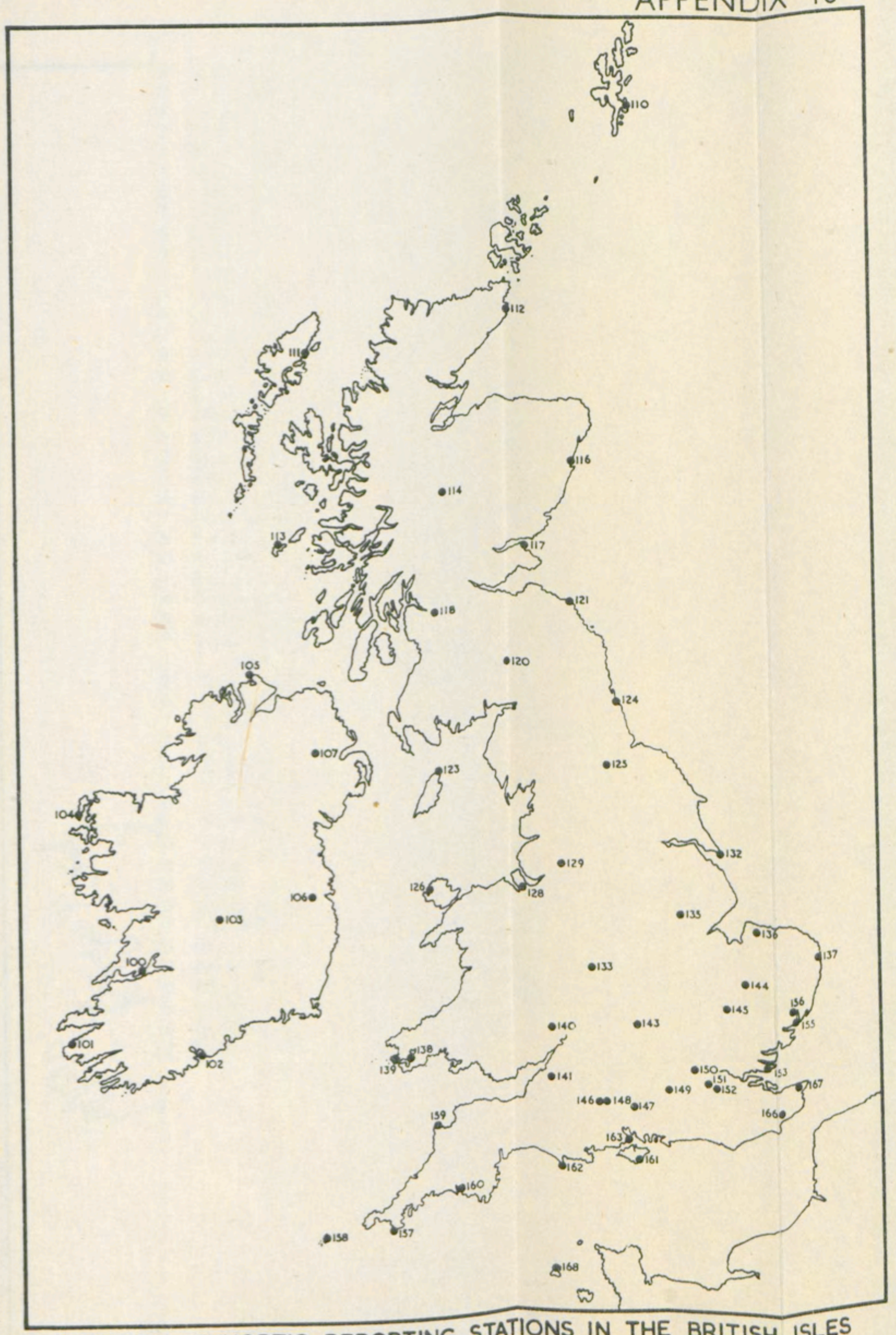
Type 1 = Main forecasting centre.
Type 2 = Subsidiary forecasting centre.
Type 3 = Distributive centre.
Type 4 = Reporting unit.



PRINCIPAL METEOROLOGICAL STATIONS
ICELAND



METEOROLOGICAL STATIONS IN THE AZORES



PRINCIPAL SYNOPTIC REPORTING STATIONS IN THE BRITISH ISLES
SEPTEMBER 1939

100 Shannon Airport
101 Valentia
102 Roches Point
103 Birr Castle
104 Blacksod Point
105 Malin Head
106 Baldonnell
107 Aldergrove
110 Lerwick
111 Stornoway
112 Wick
113 Tiree
114 Dalwhinnie
116 Aberdeen
117 Leuchars
118 Abbotsinch
120 Eskdalemuir
121 St. Abb's Head
123 Point of Ayre
124 Tynemouth
125 Catterick
126 Holyhead
128 Sealand
129 Manchester
132 Spurn Head
133 Birmingham
135 Cranwell
136 Bircham Newton
137 Gorleston
138 Pembroke Dock
139 Pembroke
140 Ross-on-Wye
141 Bristol
143 Upper Heyford
144 Mildenhall
145 Duxford
146 Larkhill
147 Worthy Down
148 Boscombe Down
149 South Farnborough
150 Kew
151 Croydon
152 Biggin Hill
153 Shoeburyness
155 Felixstowe
156 Martlesham Heath
157 Lizard
158 Scilly
159 Hartland
160 Plymouth
161 St. Catherine's Point
162 Portland Bill
163 Calshot
166 Lympne
167 Manston
168 Guernsey

9753.- 36844- 3/54. (M.F.P.)

APPENDIX 19

PRINCIPAL SYNOPTIC REPORTING STATIONS IN THE BRITISH ISLES
APRIL 1944

053 Market Harborough
100 Shannon Airport
101 Valentia
102 Roches Point
103 Birr Castle
104 Blacksod Point
105 Malin Head
107 Aldergrove
108 Collinstown
109 Hatston
113 Tiree
114 Dalwhinnie
115 Cape Wrath
117 Leuchars
118 Abbotsinch
120 Eskdalemuir
121 St. Abb's Head
124 Tynemouth
125 Catterick (Scorton)
132 Spurn Head
135 Cranwell
136 Bircham Newton
137 Gorleston
139 Pembroke
140 Ross-on-Wye
141 Bristol
144 Mildenhall
148 Boscombe Down
149 South Farnborough
151 Croydon
153 Shoeburyness
155 Felixstowe
157 Lizard
158 Scilly
160 Plymouth
162 Portland Bill
166 Lympne
167 Manston
200 Sullom Voe
204 Wick
206 Alness
210 Lossiemouth
211 Fraserburgh
215 Dyce
219 Benbecula
230 Oban
245 Montrose
246 Donibristle
253 Machrihanish
256 Prestwick
263 Charter Hall
269 Acklington
275 Bishops Court
277 West Freugh
278 Stranraer
279 Silloth
288 Thornaby
292 Linton
301 Squires Gate (Blackpool)
304 Ringway
309 Hawarden
311 Ashbourne
321 Finningley
323 Driffield
333 Penrhos
337 Aberporth
340 Ternhill
348 Grantham
350 Cranfield
368 St. Athan
379 Little Rissington
382 Abingdon
390 North Weald
394 Bradwell
400 Detling
409 St. Eval
413 Exeter
422 Poole (Hamworthy)
429 Thorney Island
500 Sumburgh
504 Stornoway
570 Eglington
575 Castle Archdale
580 Jurby
589 Millom
600 Valley
618 Snaith
634 Shobdon
640 Lichfield
642 Wymeswold
650 Honiley
671 Fairwood
673 Chivenor
675 Yeovilton
676 Lyneham
709 St. Mawgan
729 Blyton

APPENDIX No. 20

AN ACCOUNT OF THE SCIENTIFIC INVESTIGATIONS UNDERTAKEN ON BOARD S.S. ARAKAKA AND S.S. TORONTO CITY

1. Exposure and Efficiency of Instrumental Equipment

The problem of obtaining trustworthy instrumental observations at sea is largely one of securing a satisfactory exposure of the instruments.

The following notes summarise the experience gained on board these two ships, in this respect.

(a) Thermometers and Hygrometers

The following methods of obtaining wet and dry bulb readings were available :—

(i) Thermometers exposed in a ship's screen.

(ii) Assmann psychrometer.

(iii) Distant reading psychrometer (thermograph).

On the *Arakaka* three standard positions were used for the ship's screen. Rather better precautions were taken aboard the *Toronto City* :—

'The screen was exposed on the weather side of the ship suspended from a hook in a beam near the ship's side. Vertical supports were also fitted, one each side of the ship, to which the screen could be fixed by two metal hooks attached to the back. This latter method of support was used in very rough weather when it was dangerous to hang the screen on the hooks. On moderate and strong winds the screen was used for measuring wet and dry bulb temperatures, the screen being exposed some 15 minutes before the observation, on the appropriate site on the weather side of the ship. When the wind relative to the ship was light, however, it is probable that the screen temperatures were not representative of the air over the sea and the Assmann psychrometer was used as a check in such cases, its readings being accepted when the instruments differed. The psychrometer (Assmann) was exposed by suspending it from a support driven into the ship's side or by holding it at arm's length over the side of the ship—in both cases on the side. The instrument is aspirated by clockwork and there is reason to believe that the thermometers do not always attain the temperature of the air before the mechanism has run down. Provided the screen is properly exposed and that the thermometers are kept free of salt spray by frequent cleaning and changing of the wet-bulb muslin and water, this method of obtaining temperatures is preferable. On days with light winds the screen was allowed more than 15 minutes to adapt itself to the air temperature.'

The Instruments Branch have confirmed that the clockwork Assmanns are occasionally unsatisfactory, inadequate ventilation resulting in faulty readings.

On the *Toronto City* a series of check readings showed that instruments exposed on the lee side of the ship gave results unreliable by some 1° F. The distant reading thermograph, giving a continuous record of dry and wet bulb temperature, was exposed with the bulbs in a screen on the ship's rail forward of all obstructions on Monkey Island, some 3 feet above the deck of that structure. Its position is some 40 feet above the water line where the flow of air was not impeded by the superstructure of the ship (foremast excepted).

'Soon after the *Toronto City* reached the Atlantic the thermograph screen was subjected to winds exceeding 60 knots and the strain produced a distortion of the cross section of the screen from its original rectangular shape. This circumstance gave rise to anxiety, but experience has shown that the screen is strong enough to withstand this treatment.'

'The record of this instrument is liable to four sources of error which must be guarded against :—

(i) In high winds and rough seas is carried into the screen so that the muslin and both thermometers become contaminated with salt. It is necessary to change the muslin and water and clean the thermometers at least three times a week.

(ii) The actual deposit of salt water on the thermometers in very rough weather directly affects the record, producing an uneven trace fluctuating between sea surface and air temperature. This is unavoidable.

(iii) The evaporation from the muslin is so great in the winds characteristic of the Atlantic Ocean that care is required to ensure that the trough does not become dry. Normally, changing of the water three times a week is sufficient to avoid this. It is sometimes extremely difficult to refill the trough in high winds.

(iv) The dry bulb and the exposed part of the wet bulb become corroded as a result of the action of the salt deposits, the lead covering being fitted as a consequence. There can be no doubt that copper sheaths should be fitted to the bulbs of instruments for use at sea.

When there is a large change of temperature with height, it is not to be expected that the thermograph and screen will give comparable results, but in winds such as are usual over the Atlantic, a considerable measure of agreement should be achieved. The following table shows the results of the comparison of the two instruments.

Wind Force	Distant Reading Thermograph					
	Greater than Screen			Less than Screen		
	within 1·5	1·0	0·5°	within 0·5	1·0	1·5
6 or less (gusty)				6	3	
Not gusty		1	5	47	18	6
Over force 6 (gusty)				31	4	2
Not gusty		3	6	38	3	2

As to be expected, the greatest discrepancies occur with the lighter winds under stable conditions (*i.e.* non-gusty winds). With the sea surface warmer than the air temperature as it normally is at this time of the year, the air at screen level may be expected to be from 0·5 to 1·0° F. warmer than the air at the thermograph level, 20 feet above. In warm stable air over a colder sea the reverse effect may be expected. This latter effect is practically unaffected by the wind force. Strong gusty winds are of course usually to be expected in polar rather than in tropical air so that there are no cases of the thermograph recording a higher temperature than the screen in these cases, even with lighter winds in unstable conditions.

In strong gusty winds with showers the thermograph trace becomes very uneven, varying through 5° F. or more in a few minutes. In view of these fluctuations the agreement between thermograph and screen must be considered very good.'

On the *Arakaka*, 'it had originally been intended to erect the screen for the thermograph on the forecrosstress; after consideration of the extreme difficulty of changing the wick and filling the reservoir, and on the strong advice of Cdr. Cresswell (P.M.O. Liverpool) who knew the Newfoundland climate well, the screen was erected on Monkey Island, forward of the machine-gun post. The exposure is bad for aft winds; a bad exposure in one direction at least is of course an inevitable evil on board a steamship.'

The following remarks may be of interest :—

'. . . the position and screening of the bimetallic thermograph and hair hygrograph were the result of a compromise between the need for a good exposure, protection of the instruments, accessibility in all weathers, and the arc of fire of the guns. It was expected that the recordings would not agree absolutely with the psychrometer and screen temperatures, or with the records of the distant reading thermograph. But the records are similar in shape and this is the most important requirement for synoptic analysis. The thermograph answers quickly to an alteration in the air temperature. The hygrograph is less quick in its response to humidity changes but shows the rapid fluctuation due to showers.

Difficulty is experienced during rough and wet weather in changing the charts, and in preventing the pens from leaving the charts in severe rolling. Tests against thermometers and the Assmann psychrometer placed in the screens have shown that the instruments are recording accurately the screen conditions.

Changes in the ship's course are responsible for many sudden changes in the autographic records and this must be born in mind when comparing the charts.'

Anemometers

The behaviour of the cup anemometers in use on both ships cannot be regarded as entirely satisfactory. On the *Arakaka* three electric cup anemometers and one airmeter (Negretti & Zambra) were carried. The four instruments were tested against each other and were found to agree over a large range of velocities, the differences being less than 10 per cent. This was regarded as all that could be expected in a rolling ship owing to the difficulty of keeping the instruments absolutely horizontal during test.

An electric cup anemometer was erected on the forecrosstrees, 40 feet above the deck. For a week good results were obtained and then it was found that the gears were slipping and that the axis was out of tune. Excessive engine vibration and strong winds were suggested as the reason. This was made :—

'After the first week in the area it began to appear evident that the electric cup anemometer in the forecrosstrees was reading low, and tests against two other anemometers held in the boxes confirmed this . . . . This anemometer probably requires only oiling and cleaning.'

On the *Toronto City* the cup anemometer was erected on an eight-foot post on Monkey Island.

'The exposure was the best that could be achieved for all wind directions but it was found that with a very strong wind from certain directions the ship itself caused such violent eddies (revealed in a startling manner when releasing Pilot Balloons) that the wind at the anemometer was inclined to the verical and the reading consequently gave an underestimate of the relative wind. The error was only appreciable for wind from a particular apparent direction and of force exceeding 8 and it was usually possible to estimate the error by an examination of the way in which the wind varied from point to point on Monkey Island.'

On the second voyage the eight-foot post was replaced by one 18 feet long so that the anemometer was now 60 feet above the sea surface. This position was then considered free of the eddies caused by the superstructure of the ship.

The following comments were made on the fifth voyage :—

'After six months of satisfactory service, the instrument has become less reliable.

The causes are two :—

(*a*) Friction which was not noticeable during earlier voyages, is becoming an important factor. At low and moderate wind speeds there is an intermittent and sometimes violent squeaking and groaning from the instrument. At the end of each voyage, and when possible during each voyage, the bearings are oiled in an effort to eliminate this, but with only a temporary improvement. It is often difficult to dismantle the anemometer in rough weather. Comparison with the wind in the lower layers calculated from pilot balloon ascents shows that the error introduced by the effect of friction is negligible but the situation is not entirely satisfactory.

(*b*) Vibration of the ship has occasionally separated the spindle from the cogs of the wheel with which it engages so that electrical contacts are no longer made. This fault is infrequent and may usually be soon rectified.

Though these faults are not serious it is thought that a spare instrument should be carried in case of more obstinate trouble.'

Barometer and Barograph

Comments regarding the difficulty of reading the mercurial barometers are as follows :—

s.s. *Arakaka* :—

'The reading of the barometer was made difficult owing to "pumping" the amplitude being a full millibar in rough weather.'

s.s. *Toronto City* :—

' . . . considerable fluctuations were observed in rough weather when the ship was rolling or pitching heavily and some difficulty was experienced in obtaining a reliable mean reading. On occasions it was found that by using both barometers it was possible to obtain a more reassuring result than by using one above—there is reason to believe that both barometers do not necessarily react in exactly the same way to heavy rolling. For this reason it is considered desirable to retain the two barometers in their present positions.'

'The pumping effect of the mercurial barometers was again experienced. The normal amplitude of oscillation is about 0·4 mbs. on either side of the mean position but may in rough weather reach 0·6 or 0·7 mbs. By averaging the highest and lowest positions of the top of the mercury column a result reliable to 0·1 mb. may be obtained in all but very rough weather.'

Neither the Aneroid, Mark I, nor the Paulin type were regarded as satisfactory.

' It had been hoped to use the Paulin aneroid for the estimation of heights of seas. This proved impossible due to the method of construction of the aneroid, the method of reading and wind pumping. The results obtained were over twice as great as the heights estimated by the more normal methods.'

The barographs were supported on special rubber mats which were successful in damping the vibration of the ship. Distortion of the traces however was produced by suction effects. The *Toronto City* reports :—

' On several occasions discrepancies have been observed between the readings of this instrument and those of the mercurial barometers. Generally the barograph reads low with a high and rising pressure but the divergence is by no means regular though it exceeds 1 mb.'

The barograph clocks behaved rather erratically. After a replacement had been made on the *Toronto City* we have the following comment :—

' A new barograph clock was fitted but this again proved somewhat erratic normally losing 60 to 90 minutes per week. It seems probable that the vibration of the ship affects the reliability of the clock, in view of the similar determination in the time-keeping of the distant reading thermograph.'

2. Upper Air Observations

(*a*) *Pilot balloon ascents*

Each ship was equipped with a Keuffel and Esser Marine theodolite. Each instrument proved defective and limited the possibilities of making successful ascents. The difficulties introduced by the rolling, pitching and yawing of the ship appeared insuperable at first to both observers, yet with time successful observations were made, using on the one hand the theodolite and on the other, sextant and compass, or a combination of both methods.

Difficulties and progress made in overcoming them are illustrated by the following quotations :—

1st Voyage *Arakaka*

' This (the theodolite) was received in poor condition, partly rusted by sea water and with the line of collimation not horizontal.

Several attempts were made to carry out pilot balloon ascents but all failed to reach above 2,500 feet owing to the violent motion of the ship and the unsatisfactory state of the theodolite.'

1st Voyage *Toronto City*

' Several 150-inch balloons were followed by this theodolite but only one ascent resulted in measurements sufficiently accurate for inclusion in a report. In a small ship such as the *Toronto City*, and in seas such as were encountered during this voyage, it is extremely difficult to obtain accurate readings. While it is possible to keep the balloon in the field of view the issue of the horizon is itself continually in motion and the superposition of the two images becomes very difficult. It is thought however, that with further practice it will be possible to obtain reliable results even on occasions of moderate swell.'

2nd Voyage *Arakaka*

' Ascents were possible on 10 days and 20 ascents were made in all, apart from cloud height balloons. Of these 20, 16 were made by the sextant and compass method, the average height reached being 4,700 feet and the greatest height being 15,400 feet. The remaining four ascents were made with the sextant for the altitude and the Keuffel & Essen theodolite for the azimuth.

The chief difficulty with the sextant and compass ascents was the unsteadiness of the " air " compass, which had an oscillation of 10 degrees. It is strongly recommended that a liquid compass be fitted instead. The azimuth mirror of the compass is not very accurate above an elevation of 45 degrees ; this is an inherent fault and is not of great importance.

It was explained in the last report that the line of collimation of the theodolite was out of adjustment, the horizon appearing very low in the field of view. This precludes accurate elevation observations on a " lively " ship, but should not affect the azimuth readings for which the horizon can be ignored. For this reason it was hoped that a combination of the sextant for elevation and the theodolite for azimuth would give the best results. The liveliness of the ship however made this method less satisfactory than the first.'

On the 3rd voyage, ' rough weather ruled out pilot balloon ascents on all but a few days and only 17 ascents were made. The average height reached was 3,500 feet the maximum height 15,400 feet and again the sextant and compass method was the more successful.

The R.A.F. sextant supplied for pilot balloon work proved disappointing as the micrometer screw had a range of only 10 degrees, and it may therefore be necessary several times during an ascent to unclamp the mirror, rotate 10 degrees by hand, return the micrometer screw to zero, and, finally find the balloon again. This is impracticable. Furthermore, the sextant has only an artificial horizon, provided by a bubble, and the bubble is far too unsteady for work on a rolling ship.'

On the fourth voyage of the *Toronto City* :—

' It has been found possible to overcome the difficulties caused by the fault in the theodolite. This fault was due to the fact that the base of the theodolite did not make a true right angle with the gimbal unit so that for certain directions the image of the horizon did not fall near the " horizontal " cross wire when the theodolite was assembled. By re-orientating the tripod however, it is possible to bring the image of the horizon reasonably near the centre of the eyepiece and by these means some successful ascents have been made. It is probable that this is due as to the improved technique . . . '

' Under nearly all conditions the ship yaws several degrees on either side of the true course. The method adopted to avoid this source of error has been to enlist the assistance of one of the ship's officers who stands by the compass and reads the deviation from the course as each reading of the balloon's co-ordinates is made.'

On the sixth voyage :—

' It may be well to repeat that three men are necessary for an accurate measurement of upper winds, viz. : one man to follow the balloon with the theodolite, one to record the displacement of the balloon, and one to read the compass at the time of each observation. The first two functions may not be combined, as is the case for ascents from land stations, since the image of the balloon is liable to move through ten degrees on either side of its mean position due to the yawing of the ship and there is consequently no position ascertainable to which the theodolite may be adjusted in order to search for the balloon once it is lost. The second and third functions may not be performed by one man owing to the impossibility of setting up the theodolite sufficiently near the compass . . . .

In all 29 successful ascents were made, the results of 24 of which were included with reports. Many of these followed more than one attempt to avoid the lower cloud layers. The average height reached was 4,200 feet and the greatest height 9,100 feet, an indication of the unfavourable weather conditions since those balloons which were not lost in cloud were obscured by the mist which, with fog, characterised much of the weather experienced in the reporting area . . . .

Neither in the case of pilot balloon ascents nor of nephoscope observations has the use of a sextant been found to be profitable. The mechanical difficulties of following the balloon by means of the theodolite have been largely overcome and ascents may be followed as far as the cloud base and visibility will permit.'

(*b*) *Nephoscope observations*

The procedure evolved on board the S.S. *Arakaka* was as follows :—

' (i) The ship's course is altered to give least rolling ; the engineers may be asked to stop the funnel smoke.

(ii) One observer stands by the magnetic compass with the stopwatch and working sheet.

(iii) The most suitable section of cloud is chosen, a balance being struck between the need for a high elevation, distinctness, constancy of shape and a horizon.

(iv) When the observer with the theodolite has got the cloud fragment in the middle (laterally) of the field of view and level with the horizon, and the ship is steady (which can be judged from the motion of the cloud itself in the field of view), he calls " reading ". The stop-watch is then started and readings of theodolite and compass are taken.

(v) The cloud fragment is followed for at least five minutes (if possible) and sometimes up to 20 minutes. The time depends on the conditions, five to ten minutes being sufficient if conditions are good. Readings are taken every one, two or three minutes according to conditions. Care is taken that the final reading should be taken with the ship steady thus ensuring an accurate azimuth.

(vi) Further observations are then taken on other pieces of cloud, anything up to five to ten in number.

(vii) Finally the ship's speed and the compass error are obtained from the ship's officers. These are accurate to half a knot and two or three degrees.'

Further details may be found in the fifth report of work.

(*c*) *Radiosonde Work*

No radiosonde ascents proper were ever made from these ships but a certain amount of preliminary work was done.

Commander Hennessy M.O.1, together with Mr. Lander visited both ships when in dock and arranged for various alterations to be made. Details are available.

On the third voyage of the *Arakaka* trial launchings of balloons were made :—

' During the voyage nine trial launchings were made with the balloon launcher in all winds up to force 6. The only difficulty was with a force 6 wind, when three men were needed to haul up the launcher and even then the balloon broke out of the launcher before the actual release. With more practice and by using the storm trysail as a wind shield it is hoped to launch the balloon successfully in a force 7 wind. The ship must be almost broadside on to the sea for launching and so launching will probably be impossible in a wind of force 8 because of the danger of the open hatch and the rolling ship.'

Successful trial releases were also made on the *Toronto City* during the third voyage :—

' Successful trial releases have been undertaken as a result of an improved technique involving the use of guide ropes and the effective collaboration of the Bo'sun and several seamen. As soon as the instruments are available it should be possible to maintain a frequent and regular series of ascents.'

3. The Measurement of Sea Temperature

Three methods of measuring sea water temperature were available :—

(i) Canvas bucket.

(ii) Lumby sampler.

(iii) Intake.

The canvas bucket was found to be very easy to use, though it deteriorated very rapidly, being of poor workmanship. The Lumby sampler was difficult to use, especially in rough weather and did not withstand rough treatment. The following remarks are significant :—

' A Lumby water sampler was also carried and a cable was fixed in position so that the sampler could be used. The instrument is a heavy brass cylinder which is towed through the water and is so constructed that a continuous stream of water flows through it. It contains a thermometer and a bottle for sea water samples. There is no doubt that this is a more accurate method of measuring the temperature of the sea surface but the instrument itself is so heavy and cumbersome that it is difficult and even dangerous to raise and lower it in rough weather. Tests carried out showed little or no difference in the results obtained by the two methods on those occasions when both were used, so that the canvas bucket method was always employed when the weather conditions rendered the use of the Lumby sampler difficult or impossible.'

Experience on the second voyage of the *Toronto City* is summed up as follows :—

' It is most important that the temperature of the water sample obtained in the canvas bucket be read immediately it has been obtained. Evaporation from the surface in strong winds and loss or gain of heat by radiation and conduction, cause the temperature of the sample to change quite appreciably. The thermometer rapidly assumes the temperature of the sample and it should be read as soon as it becomes steady.

The bucket is now used exclusively for obtaining sea surface temperature on account of its greater convenience, but the following table may be of interest, comparing temperature obtained by this method and by the Lumby water sampler, as well as the temperature of the water of the intake to the ship's engine room some 15 feet below the surface. The figures confirm previous investigations. Temperatures are in ° F.

Lumby Sampler	Bucket		Intake (15′ below Surface)
	Same Side	Opposite Side	
49·3	49·4	49·7	—
54·7	54·8	54·9	53·0
55·1	55·3	55·4	53·0
58·4	58·3	58·4	58·5
52·4	53·0	53·2	53·0
34·3	34·8	34·8	35·0

The intake gives a reliable answer only when the sea is rough and the water consequently well mixed in the upper 15 feet.'

On the third voyage the agreement of readings of the Lumby water sampler and the temperature of water obtained in canvas buckets was again very good. It was stated that the values of sea temperature observed and reported were accurate to within 0·2° F.

The following comments on the Lumby sampler were made as a result of experience on the *Arakaka.*

' Over a series of 12 tests the temperature from the sampler was on the average 0·3° F. higher than the temperature given by the bucket, and in no case was the sampler temperature the lower of the two. This is probably due to two causes. First, the cooling of the bucket as in all cases the air was colder than the sea. Second, the " diving " of the sampler beneath the surface though how much this would affect the reading is unknown.

Bad weather restricted the tests because if the ship is rolling much the sampler is continually being pulled sharply against the ship's side ; the brass sockets on the head of the cylinder were damaged in this way. Similarly it is impossible to keep the instrument on the surface unless the ship is steady.

It must be stressed that the sampler is not a practicable method of taking temperatures for hourly observations. The operation needs two men and takes about a quarter of an hour to do, and is not possible at night or when the ship is rolling badly. Finally, as stated above, the sampler does not stand up well to constant use.'

4. Estimation of Wind Force from State of Sea (Berlin Specification)

The following table based on experience in the *Toronto City* shows occasions when estimates of wind made from the state of sea did not conform with wind speeds deduced from anemometer readings and the course and speed of the ship.

Beaufort Number	Total Occasions	Number of Cases in which State of Sea gives			Remarks	
		True Estimate	Under Estimate	Over Estimate	Under Estimate	Over Estimate
0	2			2		Similar to force 1 with occasional white horses.
1	2	2				
2	3	1		2		As force 2, with some white horses due to heavy swell.
3	16	9	2	5	Crests not breaking, general glassy appearance.	Fairly frequent white horses with some spray (heavy swell).
4	13	11	2		Scattered infrequent white horses.	
5	41	30	8	3	Occasional white horses with little or no spray.	Extensive white patches with spray. Many foam streaks.
6	46	39	2	5	Sea as force 5, wind recently freshened.	Streaks of foam well marked, much foam.
7	45	29	7	9	Some foam crests. No streaks of foam visible.	Spray with dense streaks of foam along wind.
8	43	39	2	2	Many streaks of foam with some large patches.	Dense streaks of foam, extensive foam patches, much spray.
9	20	15		5		Large patches of foam, sea has white appearance, visibility affected.
10	8	8				
11	2	2				

Most of these observations were made during the day. Observation of the sea surface on a dark night is unlikely to give a reliable estimate of the wind except in cases of force 9 or over.

In the majority of cases where the state of the sea gives an over-estimate, the appearance of the sea still retains the characteristic appearance of a previous higher wind force.

' The appearance of the crests of waves and the spray and foam produced by the wind from the wave crests forms one of the best criteria for estimating wind force at sea, and though there are cases where the state of the sea is not a reliable guide to wind force, yet, in general, confidence may be placed in the following table of correspondence between wind force and the various phenomena of breaking crests.

Description of Wave Crests, etc.	Wind Force	
	First becomes Noticeable	Characteristic
White horses (scattered)	(Rarely) 2	3
White horses	—	4
White horses (frequent)	—	5
Spray	5	6
Streaks of foam	Occasionally 6	7
Spindrift	7	8
Dense streaks of foam	8	9
Large patches of foam, sea becoming white	9	10
Sea completely white	11	12

These figures apply to the case where the wind is increasing. In the particular case of spindrift, 30 knots appears to be the critical wind speed, at which small amounts of spindrift first appear. Occasional traces have even been observed at 28 or 29 knots but this is unusual. By the time the wind has attained force 8 spindrift is nearly always present.

The following information was given as a result of experience on the s.s. *Arakaka* :—

' (*a*) *Foam streaks.* These may be observed without difficulty with force 6 winds and with rather more difficulty can be made out with force 5 winds. The Berlin specification states that the streaks begin with force 7 winds—a definite mis-statement.

(*b*) *Spray.* Spray is prevalent with force 7 winds ; no mention is made of this in the description.

(*c*) *Spindrift.*—On only one occasion was spindrift noted with a force 7 wind.

(*d*) Force 8. The breaking waves begin at force 8 to give not only white foam patches, but also light green patches, as more and more of the mass of the waves curls and breaks, and not merely the extreme crest. These patches are very noticeable and make an extra criterion for force 8 winds.

Apart from these criticisms the sea descriptions are excellent.'

The following note on spindrift was also submitted :—

' On the attached sheet are given the cases of force 7 winds met with and in each case it is stated whether there was spindrift or not.[1]

Wherever possible the Beaufort number was obtained from the relative speed as given by the anemometer on the forecrosstrees, using the triangle of velocities. The anemometer is 45 feet above the deck and 55 feet above the water level and the exposure is good except for aft winds. If the wind was aft the Beaufort number had to be estimated from the sea surface and such observations are not of great value in determining when a spindrift forms. In all cases it is indicated whether the force was estimated, or taken from the anemometer, or both.

More cases of spindrift with force 7 winds were noticed than on previous voyages. It is strongly suspected that this is due to a change in the anemometer used. While in St. John's the opportunity will be taken to test this anemometer against the two other anemometers carried on board.

[1] A.M. File S.58250/11. Encl. 99A.

An additional source of error in the anemometer wind speed is the "rolling wind" for a cup anemometer in a dead calm on a stationary ship will record a wind speed if the ship is rolling. A cup anemometer will therefore read high on a rolling ship. The error is small in itself but is probably of importance when one is trying to determine whether spindrift begins with a strong force 7 wind or a weak force 8 wind.'

These investigations were, unfortunately, never completed.

5. Measurements of Sea and Swell

Both observers made observations of height of sea and swell with a view to a correlation with wind force. The fundamental difficulties were of course early realised ; thus

'There are of course many objections to this rough and ready method, for example, the ship is never completely in a trough of a wave (unless broadside on) and the height obtained is therefore too small. But the fundamental objection is that the height thus measured is the maximum height of the sea plus swell. It is quite impossible to measure the height of the sea and swell separately when both are present, and this is almost always the case, so for the purpose of correlating height of sea against wind force there are few days on which useful observations can be taken. The observations are of value provided

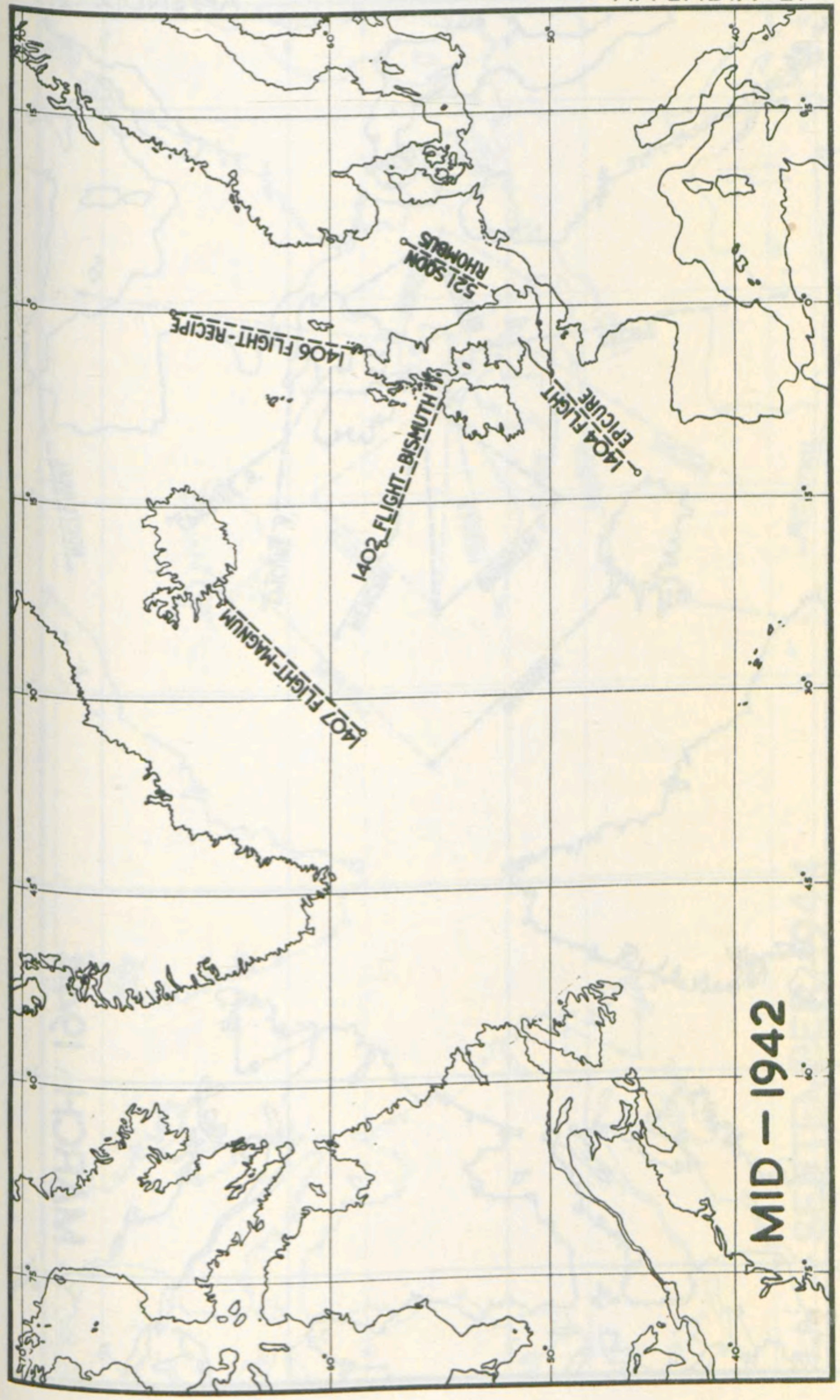
(i) There is no cross swell,

(ii) The wind is steady or increasing slowly, and

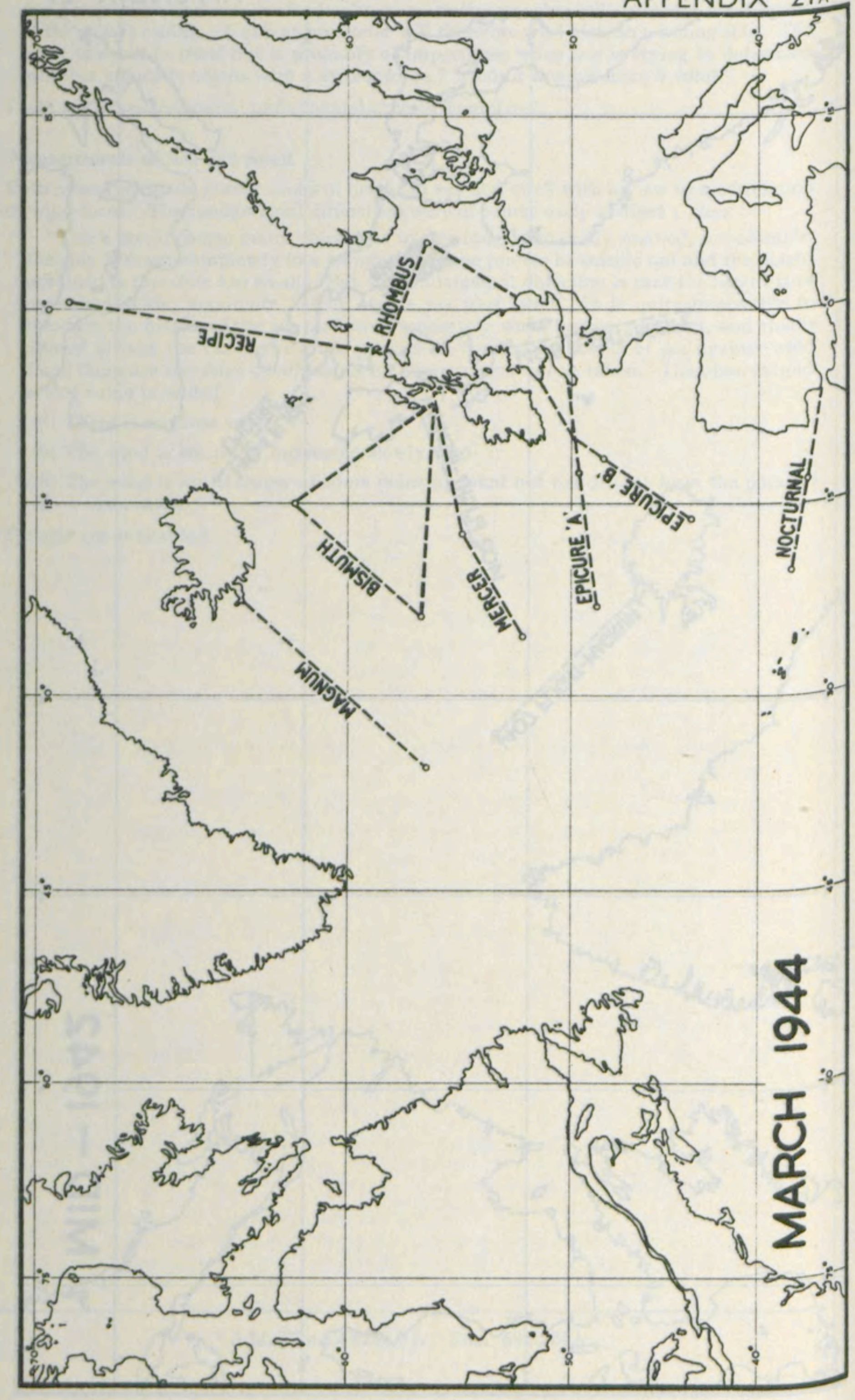
(iii) The wind is not stronger at some point up wind not too distant from the point of observation.'

Results are available.[1]

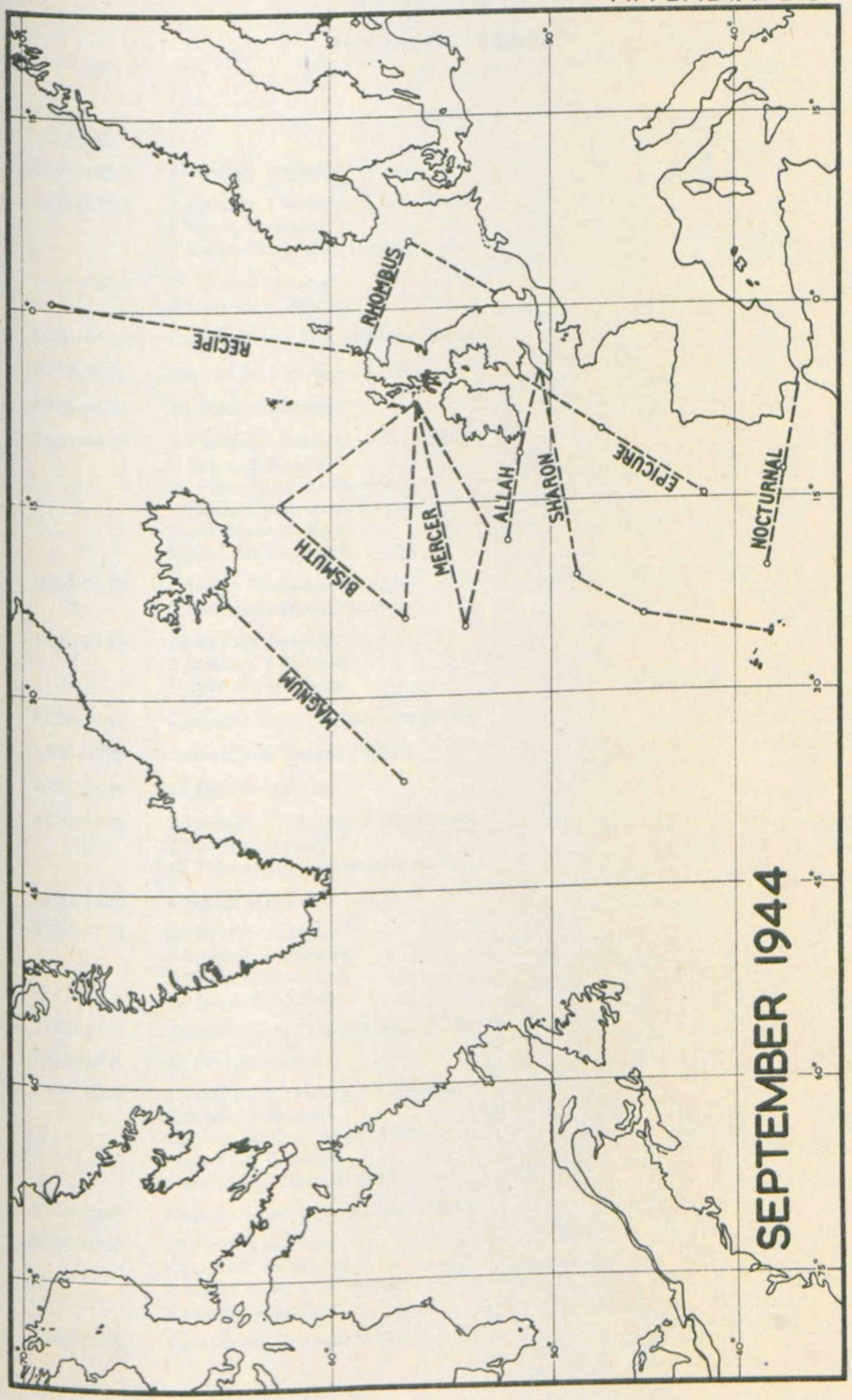
[1] A.M. File S.58250/11. Encl. 50B, 55A.



MID – 1942 METEOROLOGICAL RECONNAISSANCE FLIGHTS



METEOROLOGICAL RECONNAISSANCE FLIGHTS



METEOROLOGICAL RECONNAISSANCE FLIGHTS

APPENDIX No. 22

W/T 'ALFIG' ISSUES

Time G.M.T.	Contents
0205–0230	45 British stations.
0230–0250	3 Iceland, 1 Faeroes, 1 Greenland. 2 Spain, 2 Azores. 2 Radio Pilots and Temps.
0500–0520	25 British stations. 3 Iceland, 1 Faeroes.
0530–0550	Canadian and U.S. stations (0100).
0715–0735	Baratic and Baranal (0100).
0805–0830	45 British stations.
0830–0900	3 Iceland, 1 Faeroes, 1 Greenland. 2 Spain, 2 Azores. 12 Pilot Balloon observations. 2 Radio Pilots and Temps. 2 aircraft soundings. Upper Air Isopleths.
0900–0925	2 Radio Pilots and Temps. 2 Reconnaissance Flights.
1100–1120	25 British stations. 3 Iceland, 1 Faeroes. Upper Air Isopleths.
1130–1150	Canadian and U.S. stations (0700).
1305–1325	Baratic and Baranal (0700).
1405–1430	45 British stations.
1430–1445	3 Iceland, 1 Faeroes, 1 Greenland. 2 Spain, 2 Azores. 12 Pilot Balloon observations.
1530–1550	4 Radio Wind and Temps.
1700–1725	25 British stations. 3 Iceland, 1 Faeroes. 2 aircraft soundings. Upper Air Isopleths.
1730–1750	Canadian and U.S. Stations (1300).
1905–1930	45 British stations.
1930–2000	3 Iceland, 1 Faeroes, 1 Greenland. 2 Spain, 2 Azores. 12 Pilot Balloon observations. Upper Air Isopleths. Baratic and Baranal (1300).
2225–2245	Canadian and U.S. stations (1800).
2300–2330	25 British stations. 3 Iceland, 1 Faeroes. 2 Radio Wind and Temps. 2 aircraft soundings.
2330–2350	Baratic and Baranal (1800).

APPENDIX No. 23

W/T 'BULFEX' ISSUES

Time G.M.T.	Contents
0015–0030	Additional Upper Air Reports (Temps., Radio Sondes, Recco Flights, U/W.s, Ferats, Plobs).
0030–0100	Special F/C.
0100–0115	Additional Mediterranean 2200 G.M.T. Reports.
0115–0145	—
0145–0200	20 British 0100 G.M.T. Reports.
0200–0235	(Russia).
0235–0300	40 Mediterranean 0100 G.M.T. Reports, 20 Iberian, additional Iceland and Greenland.
0300–0330	Additional Upper Air Reports.
0330–0400	Additional 0100 G.M.T. Mediterranean Reports, etc.
0400–0450	(Russia and Iceland).
0450–0500	24 British 0400 G.M.T. Reports.
0500–0530	(Russia).
0530–0600	40 Mediterranean 0400 G.M.T. Reports.
0600–0630	Additional Upper Air Reports.
0630–0700	Additional 0400 G.M.T. Mediterranean Reports.
0700–0745	—
0745–0800	29 British 0700 G.M.T. Reports.
0800–0900	(Russia).
0900–0930	40 Mediterranean 0700 G.M.T. Reports, etc.
0930–1000	Additional Upper Air Reports.
1000–1050	(Russia and Iceland).
1050–1100	24 British 1000 G.M.T. Reports.
1100–1200	(Russia).
1200–1230	40 Mediterranean 1000 G.M.T. Reports, etc.
1230–1300	Additional Upper Air Reports.
1300–1345	—
1345–1400	29 British 1300 G.M.T. Reports.
1400–1435	(Russia).
1435–1500	Additional Upper Air Reports.
1500–1530	40 Mediterranean 1300 G.M.T. Reports, etc.
1530–1650	(Russia and Iceland).
1650–1700	24 British 1600 G.M.T. Reports.
1700–1730	(Russia).
1730–1745	—
1745–1800	40 Mediterranean 1600 G.M.T. Reports, etc.
1800–1830	Additional Upper Air Reports.
1830–1845	Additional 1600 G.M.T. Mediterranean Reports.
1845–1900	29 British 1800 G.M.T. Reports.
1900–1950	(Russia).
1950–2030	40 Mediterranean 1800 G.M.T. Reports, etc.
2030–2100	Additional Upper Air Reports.
2100–2200	RESERVED.
2200–2230	(Iceland).
2230–2245	Additional Upper Air Reports.
2245–2300	29 British 2200 G.M.T. Reports.
2300–2345	(Russia).
2355–0015	40 Mediterranean 2200 G.M.T. Reports.

APPENDIX 24

METEOROLOGICAL INSTRUMENTS

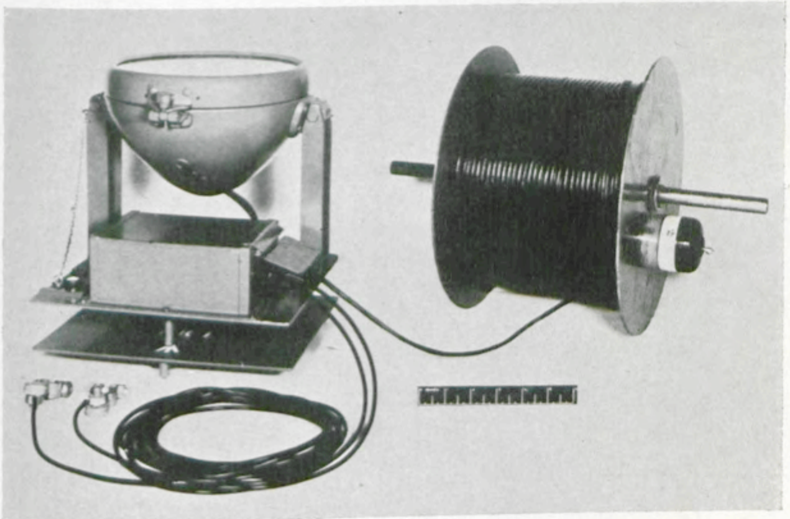


FIG. 1. PORTABLE CLOUD SEARCHLIGHT

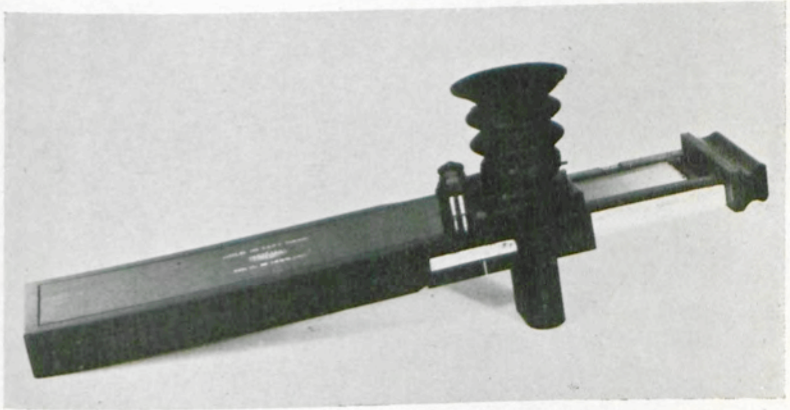


FIG. 2. NIGHT VISIBILITY METER, MARK II

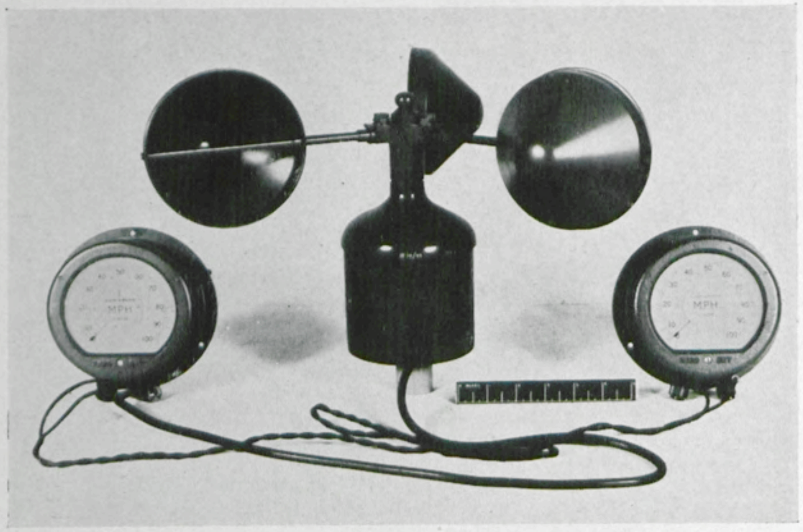


FIG. 3. REMOTE INDICATING ANEMOMETER CUP, GENERATOR PATTERN

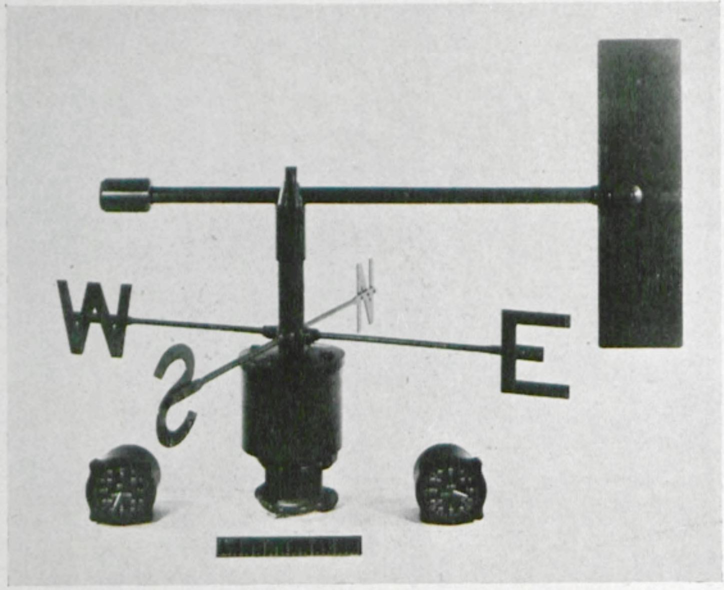


FIG. 4. REMOTE INDICATING WIND VANE—DESYNN PATTERN

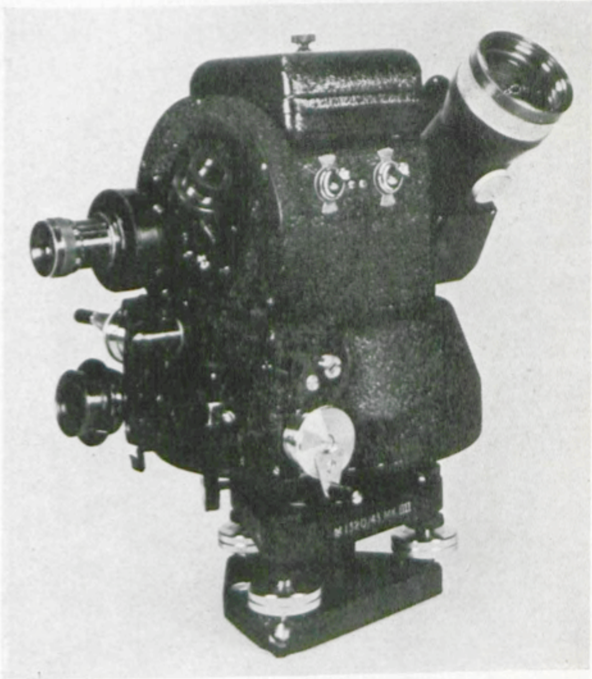


FIG. 5. PILOT BALLOON THEODOLITE, MARK IV

FIG. 6. AIRCRAFT ANEROID BAROMETER, MARK II

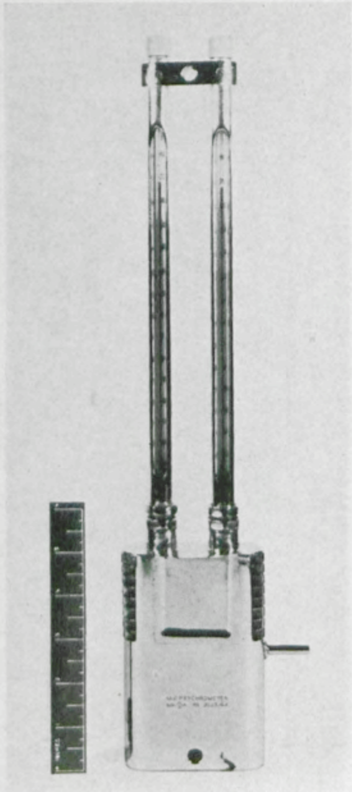


Fig. 7. Aircraft Psychrometer, Mark VIa

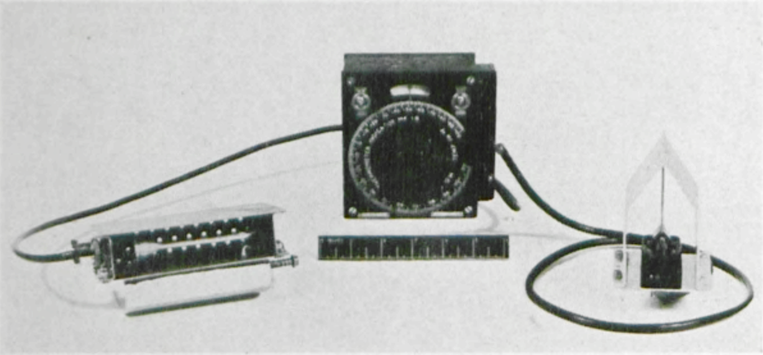


Fig. 8. Aircraft Psychrometer—Balanced Bridge, Electrical Resistance Type

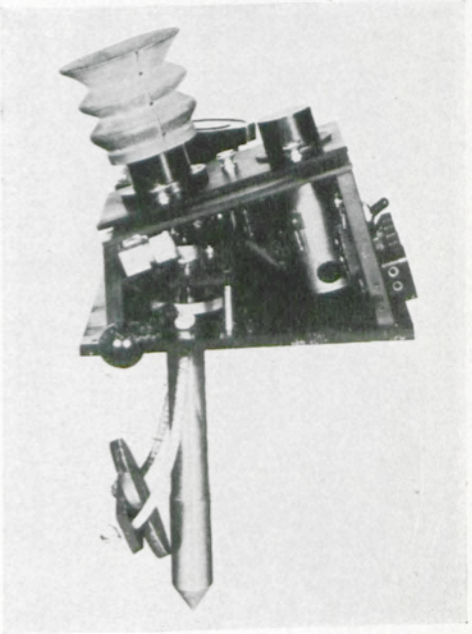


Fig. 9. Frost Point Hygrometer, Mark II

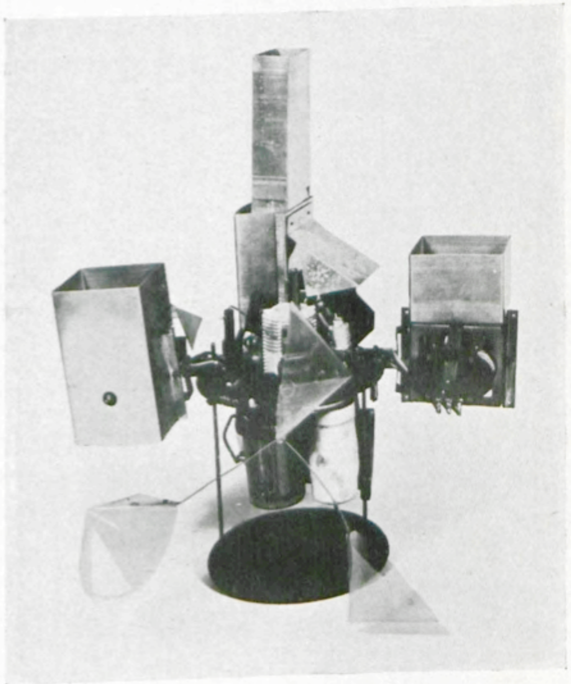


Fig. 10. Radio-Sonde, Mark Ia

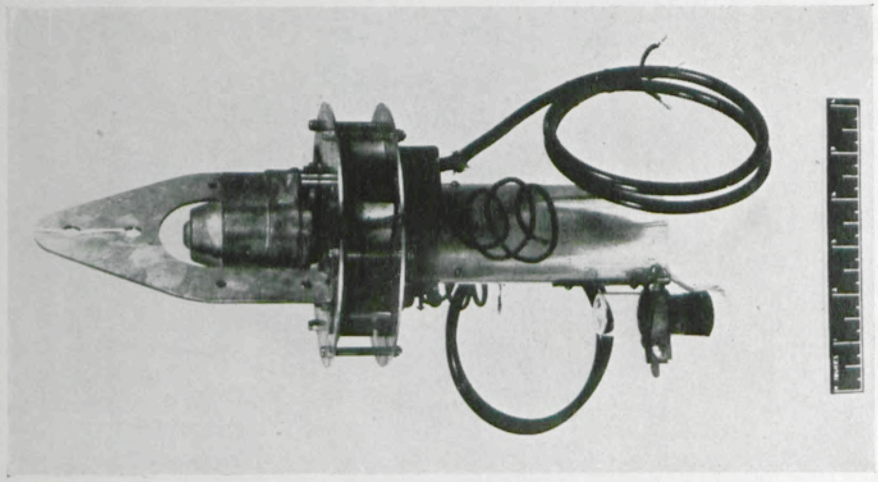


Fig. 12. Balloon Psychrometer, Electrical Resistance Type

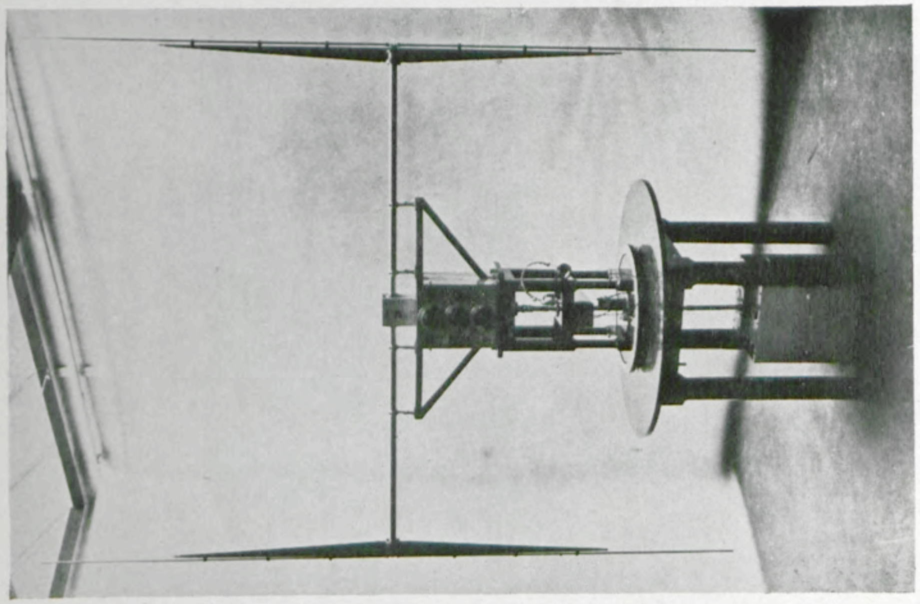


Fig. 11. Direction Finder for Upper Wind Measurement

JOINT METEOROLOGICAL RADIO PROPAGATION SUB-COMMITTEE LIST OF PAPERS PREPARED BY METEOROLOGICAL OFFICE DURING PERIOD JUNE 1943–AUGUST 1945

JMRP. No.	Title	Classification	When Published	Author
1	The Meteorological Aspects of Anomalous Propagation—Short Wave Radio.	C	June 1943	F/Lt. R. W. Hatcher.
5	Temperature and Humidity Observations at Rye, 1943.	R	November 1943	Met. Officer, Rye.
6	Vertical Distribution of Temperature and Humidity at Rye, 14–15 January 1944.	R	February 1944	
7	Analysis of Temperature and Humidity Records at Rye.	R	1944	
13	Meteorological Report in connection with V.H.F. Wireless Experiments between Aden and Berbera, 1943.	C	October 1943	S/Ldr. R. Frith.
17	Instrumental Layout for Recording Gradients of Temperature and Relative Humidity.	R	May 1944	Met. Officer, Rye.
18	Extract from Rye Records of Temperature and Humidity gradients during selected Radiation Nights, March 1944.	R	May 1944	
20	Some Extracts from Rye Records during April–May 1944.	R	June 1944	Met. Officer, Rye.
22	Seventh Meeting of Joint Meteorological Radio Propagation Sub-Committee, 13 July 1944—Progress Report.	C	July 1944	
23	Some Values of the Refractive Index of the Atmosphere at Rye.	R	1944	
24	Eighth Meeting of Joint Meteorological Radio Propagation Sub-Committee, 14 September 1944—Progress Report.	C	1944	
26	Diurnal Variation of Temperature and Humidity at various Heights at Rye—Summer Conditions.	R	October 1944	
27	Notes on T.R.E. Report T.1727—JMRP. 25—(Radio Climatology in India and Vicinity).	R	November 1944	C. S. Durst.
28	Ninth Meeting of Joint Meteorological Radio Propagation Sub-Committee, 16 November 1944—Progress Report.	C	November 1944	

JMRP. No.	Title	Classification	When Published	Author
29	Tenth Meeting of Joint Meteorological Radio Propagation Sub-Committee, 11 January 1945—Progress Report.	C	January 1945	
34	Summary of Suggestions following Minute 119 of JMRP. Sub-Committee.	R	January 1945	
41	Eleventh Meeting of Joint Meteorological Radio Propagation Sub-Committee, 15 March 1945—Progress Report.	C	March 1945	
46	Suggestions for Investigations in Radio-Meteorology.	C	1945	M.O.4.
47	Summary of Investigations on Meteorological Radio Propagation Problems.	C	1945	
48	The Slopes of Isopycnic Surfaces in the Lower Atmosphere.	R	March 1945	Dr. A. H. R. Goldie.
49	Report on an Investigation of Subsidence in the Free Atmosphere (S.D.T.M. 94).	R	September 1944	S. Petterssen. P. A. Sheppard. C. H. B. Priestley. K. R. Johannessen.
51 (and Addendum)	Note on Errors in Measurement of the Refractive Index of the Air for High Frequency Radio Waves consequent upon Errors in Meteorological Measurements.	R	April 1945	G. A. Bull.
52	Twelfth Meeting of Joint Meteorological Radio Propagation Sub-Committee, 17 May 1945—Progress Report.	C	May 1945	
55	KXS Trials—Llandudno—June to September 1944. Lower Atmosphere Radio-Meteorological Flight Technique.	R	1945	F/Lt. J. Cochemé (Met. Air Observer).
58	Report on Radar Echoes from Cloud and Precipitation observed at Sopley, Hants, March–April 1945.	C	1945	F/Lt. E. F. Carnell.
61	Radio Climatology of the Bay of Bengal and the Coastal Regions of Siam, Malaya, Sumatra and Java, prepared by F/Lt. R. W. Hatcher, Meteorological Office, S.A.C.S.E.A. for Radio Counter-measures Section, S.A.C.S.E.A.	C	1945	F/Lt. R. W. Hatcher.
62	Fourteenth Meeting of Joint Meteorological Radio Propagation Sub-Committee, 19 July 1945—Progress Report.	C	July 1945	
63	Views on Future Programme of work for the Radio-Meteorological Flight.	R	July 1945	

APPENDIX No. 26

METEOROLOGICAL OFFICE PUBLICATIONS IN THE 'M.O.' SERIES

The publications in this series, produced during the war, were classified as "Restricted."

Complete List of Naval Handbooks up to August 1945

M.O. 446a.			Weather in Home Waters and the North-Eastern Atlantic.
	Vol. I.		General Information, 1941. Revised 1943.
M.O. 446b (1).	Vol. II.	Part 1.	The Atlantic from the Azores to the African coast, 1942, with an appendix on Gibraltar, 1943. Revised 1944.
M.O. 446b (2).	Vol. II.	Part 2.	The Bay of Biscay and the west coast of Spain and Portugal, 1944.
M.O. 446b (3).	Vol. II.	Part 3.	The English Channel, 1940.
M.O. 446b (4).	Vol. II.	Part 4.	The Western Approaches to Great Britain and Ireland, 1940.
M.O. 446b (5).	Vol. II.	Part 5.	The North Sea, 1940.
M.O. 446b (6).	Vol. II.	Part 6.	The Baltic Sea, 1943.
M.O. 446b (7).	Vol. II.	Part 7.	The Norwegian and Barents Seas, 1941.
M.O. 391a.			Weather in the Mediterranean.
	Vol. I.		General Information, 1937.
M.O. 391b.	Vol. II.	Part 1.	Strait of Gibraltar to Sardinia Channel, 1936.
		Part 2.	East coast of Spain to Corsica and Sardinia, 1936.
		Part 3.	Gulf of Lions and French Riviera, 1935.
		Part 4.	Gulf of Genoa and Ligurian Sea, 1935.
		Part 5.	Tyrrhenian Sea, 1936.
		Part 6.	Sicily and Malta Channels and the east coast of Tunisia, 1935.
		Part 7.	Ionian Sea, 1936.
		Part 8.	Sea of Sidra (Sirte), 1936.
		Part 9.	Adriatic Sea, 1936.
		Part 10.	Aegean Sea, 1935.
		Part 11.	Crete to Palestine and Syria, 1935.
		Part 12.	Red Sea, 1935.
M.O. 391c.	Vol. III.		Aids to Forecasting, 1937. Revised 1945.
M.O. 391c/1.	Appendix.		Note on Recent Progress in Forecasting in the Mediterranean, 1945.
M.O. 404a.			Weather in the China Seas and in the western part of the North Pacific Ocean.
	Vol. I.		General Information, 1938.
M.O. 404b.	Vol. II.	Part 1.	The Malacca Strait.
	1937.	Part 2A.	China Sea south of latitude 10° N.
		Part 2B.	The north-west coast of Borneo.
		Part 3.	Central portion of the China Sea.
		Part 4.	China Sea north of latitude 20° N. and the Formosa Straits.
		Part 5A.	The Eastern Sea.
		Part 5B.	The lower Yangtze Valley.
		Part 6.	The Yellow Sea and the Gulfs of Pohai and Liaotung.
		Part 7.	The east coast of Korea and the coast of the Russian Maritime Province.
		Part 8A.	The main islands of Japan, Honshu, Kyushu and Shikoku.
		Part 8B.	The Bonin islands or Ogasawara Sunto.
		Part 8C.	The islands of Kokkaido and Sakhalin.
		Part 9.	The Philippine islands and the Sulu Sea.
		Part 10.	The Celebes Sea.
		Part 11.	The south-western portion of the North Pacific Ocean.
M.O. 404c.	Vol. III.		Aids to Forecasting, 1938.

M.O. 451a.			Weather in the Indian Ocean to latitude 30° S. and longitude 95° E., including the Red Sea and Persian Gulf.
	Vol. I.		General Information, 1943.
M.O. 451b.	Vol. II.	Part 2.	The Gulf of Aden and West Arabian Sea to longitude 60° E., 1944.
		Part 3.	The Persian Gulf and Gulf of Oman, 1941.
		Part 4.	The Makran coast from Gwadar to Karachi, and west coast of India to latitude 20° N., 1941.
		Part 5.	West coast of India from latitude 20° N. to Cape Comorin, 1940.
		Part 6A.	East coast of India from Cape Comorin to the Ganges delta, 1940.
		Part 6B.	Ceylon, 1940.
		Part 7.	The coast of Burma, 1940.
		Part 8.	The South Indian Ocean to latitude 30° S., 1940.
		Part 9.	Coast of East Africa from the Equator to C. Delgado, 1940.
M.O. 451c (1).	Vol. III.		Aids to Forecasting, Introduction and Part I. Indian Ocean, 1942–44.
M.O. 451c (2).			Aids to Forecasting, Part 2. North Indian Ocean, 1943–44.

Other 'M.O.' Publications Produced During the War

M.O.	Title
447	Monthly Meteorological Charts of Home Waters (Superseded by M.O.M. 402 and 402A).
448 (A.P. 1931)	Meteorological Handbook for Pilots and Navigators (2nd edition. Reprinted 1944).
450 (A.P. 1875)	Cloud Atlas for Aviators (3rd edition, 1943).
459 (A.P. 1980)	How to avoid flying accidents due to weather (2nd edition, 1943).
462	Meteorological Office Radio Sonde. Measurement of Temperature and Humidity (Radio—thum), 1943.
464	Meteorological Office Radio Sonde. Measurement of Upper Wind (Radio—Wind), 1943 (with separate Appendix IX).
469 (A.P. 3092)	A Pilot's Primer of West African Weather, 1944.
470	Meteorological Air Observer's Handbook, 1945.

APPENDIX No. 27

METEOROLOGICAL OFFICE PUBLICATIONS IN THE MISCELLANEOUS (M.O.M.) SERIES

The publications in this series, produced during the war, were classified as " Restricted."

Complete List of Aviation Metreorological Reports up to August 1945.

M.O.M.	Title
365/1	Karachi to Singapore Air Route, 1934.
365/2	Singapore to Melbourne Air Route, 1934.
365/3	Aleppo–Baghdad–Karachi Air Route, 1934.
365/4	Cairo–Cape Town Air Route, 1935.
365/5	S.E. England–Vienna Air Route, 1936.
365/6	Meteorological Report on Poland and East Prussia, 1939.
365/7	Meteorological Report on Northern Germany (2nd edition, 1945).
365/8	Meteorological Report on Southern Scandinavia and Denmark (2nd edition, 1943).
365/9	Meteorological Report on the English Channel and Northern France (2nd edition, 1943).
365/10	Meteorological Report on Abyssinia, Somaliland and Eritrea, 1941.
365/11	Meteorological Report on Bohemia, Moravia and Austria (excluding the Tyrol) (2nd edition, 1943).
365/12	Meteorological Report on Spain and Portugal, 1941 (Reprinted 1943).
365/13	Meteorological Report on Scotland (2nd edition, 1944).
365/14	An Analysis of Cloud Height and Cloud Visibility at Mount Batten. By A. Walters, 1942.
365/15	Meteorological Report on Southern England, 1942 (Reprinted 1943).
365/16	Meteorological Report on Northern Ireland, 1942 (Reprinted 1944).
365/17	Takoradi–Khartoum Air Route, 1943.
365/18	Meteorological Report on Northern Italy, 1943.
365/19	Meteorological Report on Yugoslavia and Albania, 1943.
365/20	Meteorological Report on Bulgaria, 1943.
365/21	Meteorological Report on the Alps, 1944.
365/21	Supplement No. 1. Snow Cover in the Eastern Alps, 1944.
365/21	Supplement No. 2. Special Aspects of Alpine Climate, 1944.
365/22	Meteorological Report on Arctic Scandinavia, 1944.
365/23	Meteorological Report on Middle Danube Area, 1944.
365/24	Meteorological Report on China, Japan and adjacent areas, 1945.
365/25	Meteorological Report on Southern Germany, 1945.
365/26	Meteorological Report on Northern England, 1945.
365/27	Meteorological Report on the main islands of Japan, 1945.
365/28	Meteorological Report on the Ryukyu Islands, 1945.
365/29	Meteorological Report on South China, 1945.

Other Miscellaneous Publications Produced During the War.

370	Tables of Wind Direction and Force over the British Isles (2nd edition with Supplement, 1943) (1st edition, 1939).
371	Quarterly Sectional Charts of Ocean Currents for the North and South Atlantic Oceans and Mediterranean Sea (1st edition, 1939).
372	Investigation of Winter Fog and Mist in the British Isles, 1936–37. By C. S. Durst, B.A., 1940 (Reprinted 1944).
373	Notes on Stratus Cloud near the East Coast of Great Britain. By G. A. Bull, B.Sc., 1940.
374	A Comparison of Cloud Amount over the North Sea Reported by Ships and the Cloud Amount deduced from Synoptic Charts based on Observations from Land Stations. By W. H. Bigg and C. K. M. Douglas (Reprinted 1941).
375	A Contribution to Forecasting in Iraq. Small Rotary Systems in Advance of a True Cold Front. By C. V. Ockenden, B.Sc., 1940.
387	The Helm Wind of the Northern Pennines. By G. Manley, M.A., 1940 (Reprinted 1942).

M.O.M.	Title
388	A Short Account of the Climatology of Ireland, 1940.
389	(*a*) Variation of Wind with Distance. (*b*) Variation of Wind with Time, 1940.
390	Monthly Ice Charts. Arctic Seas. Hudson Bay to Kara Seas (Revised 1944).
393	Note for the Guidance of Forecasting on the Subject of Forecasts of Ice Accretion on Airframes (2nd edition, 1943).
394	Monthly Meteorological Charts of Western North Atlantic. (Superseded by M.O.M. 402 and 402A.)
395	On the Formation of the 0° Isothermal Layer and the Building Up of Fracto-cumulus below Nimbo-stratus. (Translation of paper by W. Findeisen, Friedrichshafen in Met. *Zeit.* 57, H.2, pp. 49–54.)
397	Monthly Charts of Mean Cloud Amount, Home Waters, 1941. (Superseded by M.O.M. 402 and 402A.)
400	Meteorological Aspects of Cloud or Blind Flying. By W. H. Pick, 1941. (Superseded by M.O. 448.)
400/Polish	Do. do. Translated into Polish.
401	Visibility and Wind at Thornaby. By T. N. Harrower.
402 and 402A	Monthly Meteorological Charts of the Atlantic Ocean (bound volume).
402B	Monthly Meteorological Charts and Current Chart of the Greenland and Barents Sea.
406	Temperature of the Upper Air over England, 1941 (Revised, 1943).
407	Meteorology for the Balloon Barrage, 1941.
410	Polish Meteorological Compendium.
412	Weather of the Black Sea, 1941.
419	Some Cloud Photographs of Interest, 1943.
422	Monthly Meteorological Charts of the Western Pacific (Revised, 1945).
431	Winds at High Levels Relative to the Fronts and Occlusions of Typical Depressions. By H. Horrocks, 1943.
434	Synoptic Conditions Associated with Fog at Scilly. By H. L. Wright, M.A., 1940 (Reprinted 1943) (formerly C.D. No. 205).
435	Topographical Factors Affecting the Forecasting of Weather at Gibraltar. By A. H. Gordon, M.Sc., 1940 (Reprinted 1943) (formerly C.D. No. 211).
436	Atmospheric Opacity at certain Coastal Stations in the British Isles. By H. L. Wright, M.A., 1940 (Reprinted 1943) (formerly C.D. No. 213).
441	Charts of Rainfall over the Mediterranean Region, 1943.
442	Meteorological Codes for Communicating Information to Field Units, 1943 (Reprinted 1944).
446	Monthly Meteorological Charts of the Eastern Pacific Ocean.
447	Monthly Sea Surface Temperature and Surface Current Circulation of the Japan Sea and Adjacent Waters, 1944.
451	Monthly and Annual Maps of Average Temperature over the British Isles, 1943.
452	Variation of Temperature over the British Isles. By J. Glasspoole, Ph.D., 1944.
453	The Barometric Lows of Cyprus. By. MG. El-Fandy, B.Sc., D.I.C., 1944.
465	Monthly Ice Charts of Western North Atlantic, 1944 (Replaces M.O. 262B).
467	Statistical Methods in Climatology. By C. E. P. Brooks, D.Sc., and Nellie Carruthers, B.Sc., 1944.
468	Measurement of Upper Winds by Radar Methods (2nd edition, 1945).
469	Notes on Weather of the Far East Theatre, 1944.
470	Rainfall Maps of the Far East, 1944.
475	Organisation of the Meteorological Office in War, 1945.
476	Quarterly Surface Current Charts of Western North Pacific Ocean, 1945.

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